July 15, 2011

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# Do Patents Disclose Useful Information?

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Courts often state that patents are justified by disclosure theory, the idea that patents are awarded as quid pro quo for the public disclosure of inventions. But many commentators have argued that disclosure theory should be accorded no weight in the design of the patent system because patented inventions would have been disclosed anyway. Even the few legal scholars who dispute these economic arguments agree that, in practice, patents are currently not useful as technical sources for other innovators. This Article reorients the debate over disclosure, arguing that we do not grant patents because of disclosure—we require disclosure because we grant patents. Using results from a new survey of nanotechnology researchers and case studies of individual patents, this Article demonstrates that the benefits of disclosure are stronger than is generally believed: patents do contain useful technical information that is not available elsewhere. The benefit of further improving this technical content (and researchers' ability to find and use it) likely outweighs any resulting loss in innovation incentives. This improvement could occur through stronger enforcement of disclosure requirements (such as an obligation to respond to good faith reproducibility questions from skilled researchers), elimination of legal barriers to using patents as technical sources, and improved access to patents through peer production. These changes will help defuse the tension between patents and the open culture of science.

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## Introduction

Many have lamented the negative impact of patents on the norms of science and the "commercialization" of basic research as more universities seek patents.[1] Whether these open scientific norms are descriptive or aspirational, empirical evidence indicates that patents have decreased openness and sharing among scientists.[2] In theory, however, the standards for obtaining a patent mirror those for publishing in a prestigious peer-reviewed scientific journal: researchers identify discoveries that are useful, novel, and non-obvious, and disclose those discoveries so that other researchers can build on them.[3]

The Supreme Court has said that patent disclosures "will stimulate ideas and the eventual development of further significant advances in the art," and that these "additions to the general store of knowledge are of such importance" that they are worth the "high price of . . . exclusive use."[4] Under this disclosure theory, patents are awarded as quid pro quo for disclosing the invention (rather than keeping the information secret, such as with trade secret protection). Although disclosure theory remains popular with courts, scholars have criticized its prominence as a justification for the patent system.[5] Their

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[1] *See, e.g.*, Rebecca S. Eisenberg, *Proprietary Rights and the Norms of Science in Biotechnology Research*, 97 YALE L.J. 177 (1987); Robert P. Merges, *Property Rights Theory and the Commons: The Case of Scientific Research*, *in* SCIENTIFIC INNOVATION, PHILOSOPHY, AND PUBLIC POLICY 145 (Ellen Frankel Paul et al. eds., 1996); Arti Kaur Rai, *Regulating Scientific Research: Intellectual Property Rights and the Norms of Science*, 94 NW. U. L. REV. 77 (1999).

[2] *See* Jeremy M. Grushcow, *Measuring Secrecy: A Cost of the Patent System Revealed*, 33 J. LEGAL STUD. 59 (2004); Wei Hong & John P. Walsh, *For Money or Glory? Commercialization, Competition, and Secrecy in the Entrepreneurial University*, 50 SOC. Q. 145 (2009); Fiona Murray & Scott Stern, *Do Formal Intellectual Property Rights Hinder the Free Flow of Scientific Knowledge? An Empirical Test of the Anti-Commons Hypothesis*, 63 J. ECON. BEHAV. & ORG. 648 (2007).

[3] *Cf.* 35 U.S.C. §§ 101-103, 112 (2006).

[4] Kewanee Oil Co. v. Bicron Corp., 416 U.S. 470, 481 (1974); *see also infra* note 58 (quoting Supreme Court cases that have cited disclosure as a main goal of the patent system).

[5] *See* Alan Devlin, *The Misunderstood Function of Disclosure in Patent Law*, 23 HARV. J.L. & TECH. 401, 403 (2010) ("As a primary function of [the patent] system, disclosure is both ineffective and potentially poisonous to larger social goals."); Timothy R. Holbrook, *Possession in Patent Law*, 59 S.M.U. L. REV. 123, 146 (2006) (arguing that "disclosure obligations [are] inconsistent with the theoretical justifications of patent law"); Mark Lemley, The Myth of the Sole Inventor 49 (June 2, 2011) (unpublished manuscript), *available at* http://ssrn.com/abstract=1856610 ("Disclosure theory cannot . . . support the modern patent system."); [Benjamin

most compelling argument is that inventors will only seek patents on inventions that would have been disclosed anyway.[6] Recently, several legal scholars have defended disclosure theory from these criticisms and called for invigorated disclosure.[7] I argue that this debate should be reoriented: we do not grant patents because of disclosure—we require disclosure because we grant patents.

Although disclosure theory commentators disagree as to whether disclosure should be a central concern of the patent system, they agree that the answer to the question posed in my title is no: patents do not currently disclose much useful technical information to researchers.[8] Close examination of existing evidence, however, suggests that many researchers do use patents as a source of technical information.[9] This Article adds to the empirical evidence with a new

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Roin], Note, *The Disclosure Function of the Patent System (or Lack Thereof)*, 118 HARV. L. REV. 2007, 2028 (2005) (arguing that "the primary justification for the patent system is . . . not to encourage . . . disclosure to the public"). Criticisms of the disclosure function of patents are not of recent origin. *See* SUBCOMM. ON PATENTS, TRADEMARKS, AND COPYRIGHTS OF THE S. COMM. ON THE JUDICIARY, 85TH CONG., AN ECONOMIC REVIEW OF THE PATENT SYSTEM, STUDY NO. 15, at 33 (Comm. Print 1958) (prepared by Professor Fritz Machlup) [hereinafter MACHLUP REVIEW], *available at* http://www.mises.org/etexts/patentsystem.pdf (summarizing disclosure theory's "poor reception in [the] economic literature"); Rebecca S. Eisenberg, *Patents and the Progress of Science: Exclusive Rights and Experimental Use*, 56 U. CHI. L. REV. 1017, 1028 (1989) (describing why disclosure theory has not been particularly "popular . . . with commentators").

[6] *See infra* notes 76-78 and accompanying text.

[7] *See* Jeanne C. Fromer, *Patent Disclosure*, 94 IOWA L. REV. 539, 542 (2009) ("I disagree with this scholarship [that criticizes patent disclosure] and . . . argu[e] in favor of its centrality in the patent system."); Sean B. Seymore, *The Teaching Function of Patents*, 85 NOTRE DAME L. REV. 621, 627 (2010) (arguing in favor of strong disclosure and stating that "[i]t is now time to transform the patent into a readable teaching document"); *cf.* Dan L. Burk, *The Role of Patent Law in Knowledge Codification*, 23 BERKELEY TECH. L.J. 1009, 1012 (2008) (arguing that "many familiar provisions of the patent statute may be viewed as incentives for codification of otherwise tacit knowledge").

[8] *See, e.g.*, Devlin, *supra* note 5, at 403 ("[T]he extent to which patent documents successfully teach the inner workings of cutting-edge technologies is quite limited."); Fromer, *supra* note 7, at 560 ("[A] good deal of evidence suggests that technologists do not find that [the patent document] contains pertinent information for their research."); Lemley, *supra* note 5, at 49 ("[I]nventors don't learn their science from patents."); Roin, *supra* note 5, at 2023 ("[P]atent disclosures are very rarely a useful source of information for research and development."); Seymore, *supra* note 7, at 626 (arguing that patents are often not easily reproducible or have "little technical value" because they are "unreadable"); *cf.* Mark Lemley, *Ignoring Patents*, 2008 MICH. ST. L. REV. 19, 21 (2008) (arguing that "researchers . . . simply ignore patents").

[9] *See infra* Section I.C.

survey of nanotechnology researchers and with more detailed analysis of specific patents. The nanotech patent literature is extensive, but most nanotech researchers are academics or basic researchers who publish in traditional scientific journals. I find that even for these researchers, patents contain useful, nonduplicative technical information, and my survey data suggest that patents could be even more informative. Because my respondents' subfields ranged from nanoelectronics to drug delivery to energy, these results suggest that patents disclosures have informational benefits across a broad range of technologies.

The legal debate has focused on whether disclosure is a *justification* for the patent system, but this leads to the conclusion that because disclosure is a weak justification, patent disclosures are unimportant except as necessary to claim the invention. Given that we have a patent system, however, the relevant question is whether the benefits of strong disclosure outweigh its costs—and this Article demonstrates that disclosure has stronger benefits than previously appreciated. These benefits probably outweigh any incremental loss in innovation incentives caused by further strengthening disclosure. I suggest that enforcing and expanding upon the current disclosure requirements, and making patenting more like publishing in a premier scientific journal like *Nature* or *Science*, will help resolve the tensions between science and patent law.

This Article makes a number of distinct contributions to the growing literature on patent disclosure. First, after summarizing existing disclosure requirements and examining the current debate over disclosure theory, Part I presents the first comprehensive review of existing surveys of the technical value of patent disclosures and concludes that, counter to the claims of previous commentators, many researchers do use patents as a source of technical information. But these surveys did not include non-patenting researchers, and most of them predate the availability of patents online, so there is a need for new empirical work in this area.

Second, Part II presents the results from my nanotechnology patent survey: in October 2010, 211 nanotechnology researchers provided their thoughts on patents as a source of technical information. Nanotechnology—the interdisciplinary study of systems on the nanometer (one billionth of a meter) scale—is still an early-stage technology, and most of the respondents were academics who focus more on publications than on patents, so one would expect patents to be less useful to the respondents than to more applied industrial researchers. Surprisingly, 64% of respondents have read patents, and of them, 70% looked to patents for technical information.

Of those reading patents for scientific (rather than legal) reasons, 60% found useful technical information, indicating that patents are serving a useful disclosure function for these early-stage researchers.[10] The value of patent disclosures, however, could be improved: only 38% of the patent-reading respondents believed that the patents they were reading were reproducible, which raises serious questions about whether the current enablement standard is generally being met.

Third, this Article examines specific patents in detail—a surprising novelty in the patent literature. The case studies in Part III illustrate the findings from Part II by showing that patents contain useful technical details that are not found in the scientific literature, but that they also omit some experimental details that would be necessary to replicate the inventions without significant effort.

Finally, Part IV discusses the implications of this Article's results for patent policy and offers several novel reforms to help bridge the growing tension between patents and the open scientific culture. Although disclosure's weakness as a *justification* of the patent system suggests that disclosure only needs to be adequate to claim the invention, my reframing of the debate to look at disclosure's independent costs and benefits suggests that disclosure should be even stronger, and that access to existing disclosures should be improved, which could occur in at least three ways:

First, the U.S. Patent and Trademark Office (PTO) and the courts should more stringently enforce current disclosure requirements. I examine the costs and benefits of stronger disclosure, as well as the potential merits of allowing patentees to opt-in to enhanced disclosure. I also present the novel proposal that patentees should have an obligation to respond if a similarly skilled researcher who is trying to replicate or build on the invention asks a good-faith question about enablement (or else face a presumption of non-enablement if anyone later challenges the patent). This would enhance disclosure and bring the patent system more in line with scientific norms.

Second, as others have suggested, the courts (or Congress) should eliminate legal barriers to using patents as technical sources by clarifying that willful infringement rules do not penalize researchers for reading patents. They should also broaden the experimental use

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[10] Only 30% of *all* respondents (64 out of 211) have found useful technical information in a patent; the difference is that many respondents have never even tried to use patents in this way. For a discussion of ways to increase the number of researchers who look to the patent literature, see Part IV.

exemption, so that basic researchers can experiment with the ideas in the patents they read without fear of liability, to bring the legal rules in line with scientific norms. These doctrines currently do not deter many innovators: less than two percent of my survey respondents are avoiding patents because of infringement concerns. But laws help shape norms and expectations, so courts should adjust their interpretations of these laws to reflect current practice, rather than allowing current doctrine to negatively impact scientific culture and undermine the disclosure value of patents. A more significant legal change suggested by my survey is having patent applications published sooner than eighteen months after filing: a number of survey respondents indicated that this delay means that patents are out of date before they are even available. While mandating earlier publication for all patentees would require an act of Congress, I propose that federal grant agencies could require patents funded with federal money to be published more rapidly.

Third, I build on prior suggestions that the benefits of patent disclosures can be promoted through peer production and increased mixing of the technical and patent literature. Some respondents indicated that they would read patents if they were easier to find, and patents would be more accessible if they appeared alongside all searches of the technical literature. Peer production systems like WikiPatents could also be expanded to encourage researchers to share enabling details about patents. I also make the novel suggestions that universities could take a lead in writing helpful patent disclosures, and that scientific journals could require authors to cite relevant patents (or explain that there are no relevant patents in the field).

All of these changes will help bridge the divide between the patent literature and the scientific literature, further increasing the importance of patents as a source of technical information. Patents should be something that academic scientists are proud to list on their websites, next to their *Science* and *Nature* publications.[11] And just as scientists will benefit from this increased access to information, patent law will benefit from the increased attention from the research community.

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[11] Most academic nanotech researchers do not list their patents on their websites along with their publications. In a survey of fifty of their websites, the only exception I found was *Vivek Subramanian: Publications*, BERKELEY COLL. DEP'T OF ELEC. ENG'G & COMPUTER SCIS., http://www.eecs.berkeley.edu/~viveks/pubs.htm (last visited Dec. 25, 2010).

# I. The Disclosure Justification for Patents

This Part examines the current debate over the disclosure justification for patents. Section I.A briefly reviews the current legal standard for disclosure in the United States as interpreted by the Court of Appeals for the Federal Circuit.[12] Section I.B presents the theoretical background for the debate, reviewing the three main criticisms of disclosure theory and the responses that have been raised. Section I.C then examines previous surveys of the value of patent disclosures and concludes, despite the contrary claims of many legal commentators, that many researchers do currently find patents to be a useful source of technical information.

## A. Legal Requirements and Judicial Interpretation

Patentees in the United States must satisfy the disclosure requirements of 35 U.S.C. § 112, which sets forth the three independent conditions known as (1) written description, (2) enablement, and (3) best mode:

> The specification shall contain a *written description* of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to *enable* any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same, and shall set forth the *best mode* contemplated by the inventor of carrying out his invention.[13]

The patent specification must also include drawings "where necessary for the understanding of the subject matter,"[14] and it must "conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention."[15] No substantive changes may be made to the disclosure

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[12] The Court of Appeals for the Federal Circuit is the quasi-specialized court that has jurisdiction over patent appeals. Although the Supreme Court has made general statements about the value of disclosure theory, *see infra* note 58, it has not addressed the specific disclosure requirements under the Patent Act.

[13] 35 U.S.C. § 112 (2006) (emphasis added).

[14] *Id.* § 113.

[15] *Id.* § 112.

without changing the filing date.[16] Most patent applications are published eighteen months after filing.[17]

Enablement is the only disclosure requirement mandated by the international Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS).[18] The skilled person of § 112 is known in the patent literature as the PHOSITA (Person Having Ordinary Skill In The Art),[19] and the disclosure must enable the PHOSITA to practice the invention "without undue experimentation."[20] If an invention depends on biological materials that cannot be made without undue experimentation, the inventor must place samples of these materials in a public depository.[21]

The Federal Circuit recently reaffirmed that the written description requirement is separate from enablement, and that "the test for sufficiency is whether the disclosure of the application relied upon reasonably conveys to those skilled in the art that the inventor

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[16] *See id.* § 132(a) ("No amendment shall introduce new matter into the disclosure of the invention."). But changes to make the disclosure more enlightening could be made if the PTO and Federal Circuit "adopt a more flexible view of what constitutes 'new matter.'" Seymore, *supra* note 7, at 642 n.105.

[17] *See id.* § 122 (allowing certain exceptions, including for patents that are only filed in the United States or that have been withdrawn).

[18] *See* Agreement on Trade-Related Aspects of Intellectual Property Rights art. 29, Apr. 15, 1994, Marrakesh Agreement Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299, 33 I.L.M. 1197 [hereinafter TRIPS] ("Members *shall* require that an applicant for a patent shall disclose the invention in a manner sufficiently clear and complete for the invention to be carried out by a person skilled in the art . . . ." (emphasis added)).

[19] *See, e.g.*, Sean B. Seymore, *Heightened Enablement in the Unpredictable Arts*, 56 UCLA L. Rev. 127, 132-34 (2008) (describing the PHOSITA standard and explaining why "the PHOSITA's precise identity is crucial to enablement").

[20] *In re* Wands, 858 F.2d 731, 737 (Fed. Cir. 1988). Factors to determine whether "undue experimentation" is necessary "include (1) the quantity of experimentation necessary, (2) the amount of direction or guidance presented, (3) the presence or absence of working examples, (4) the nature of the invention, (5) the state of the prior art, (6) the relative skill of those in the art, (7) the predictability or unpredictability of the art, and (8) the breadth of the claims." *Id.* Jeffrey Lefstin has argued that most patent claims have effectively infinite scope, making it impossible to satisfy the requirement that "disclosure must enable the 'full scope' of the patent claims." Jeffrey A. Lefstin, *The Formal Structure of Patent Law and the Limits of Enablement*, 23 BERKELEY TECH. L.J. 1141, 1175 (2008).

[21] *See* 858 F.2d at 735; Lisa Larrimore Ouellette, Note, *Access to Bio-Knowledge: From Gene Patents to Biological Materials*, 2010 STAN. TECH. L. REV. N1, ¶¶ 101-103, http://stlr.stanford.edu/pdf/ouellette-access-to-bio-knowledge.pdf (describing the development of international material depositories).

had possession of the claimed subject matter as of the filing date."[22] This "possession" test is analytically distinct from enablement. The disclosure need not provide "examples or an actual reduction to practice; a constructive reduction to practice that in a definite way identifies the claimed invention" is sufficient.[23] The court gave chemical and biological examples of disclosures that would enable one skilled in the art to make an invention, but which do not describe the invention sufficiently to show that it was possessed by the inventor.[24]

The third disclosure requirement in the United States, best mode, is an optional requirement under TRIPS,[25] and it is not imposed in Europe.[26] The Federal Circuit uses a two-step test to determine whether the best mode requirement is satisfied: Step one is "a subjective inquiry, focusing on the inventor's state of mind" to determine "whether, at the time of filing the application, the inventor possessed a best mode for practicing the invention."[27] Step two is "an objective inquiry" into "whether the written description disclosed the best mode such that one reasonably skilled in the art could practice it."[28] The Federal Circuit has also stated that the best mode requirement does not "demand disclosure of every preference an inventor possesses,"[29] nor does it require "production details."[30] As applied to the facts of a specific case, a Federal Circuit panel agreed

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[22] Ariad Pharm., Inc. v. Eli Lilly & Co., 598 F.3d 1336, 1351 (Fed. Cir. 2010) (en banc).

[23] *Id.* at 1352.

[24] *Id.* at 1352-53.

[25] *See* TRIPS, *supra* note 18, art. 29 ("Members . . . *may* require the applicant to indicate the best mode for carrying out the invention known to the inventor at the filing date or, where priority is claimed, at the priority date of the application." (emphasis added)). TRIPS Article 29 does not similarly specify that members may impose a written description requirement, which raises "the issue of whether the U.S. is meeting its TRIPs obligations" by imposing a separate obligation, but the PTO has stated that the "clear and complete" requirement of Article 29 "may support both written description and enablement standards." Guidelines for Examination of Patent Applications Under the 35 U.S.C. 1211, 1, "Written Description" Requirement, 66 Fed. Reg. 1009, 1104 (Jan. 5, 2001).

[26] *See* Dale L. Carlson, Katarzyna Przychodzen & Petra Scamborova, *Patent Linchpin for the 21st Century?—Best Mode Revisited*, 45 IDEA 267, 285-86 (2005) (reviewing international application of the best mode requirement).

[27] Eli Lilly & Co. v. Barr Labs., Inc., 251 F.3d 955, 963 (Fed. Cir. 2001).

[28] *Id.*

[29] Bayer AG v. Schein Pharm., Inc., 301 F.3d 1306, 1314 (Fed. Cir. 2002).

[30] Teleflex, Inc. v. Ficosa N. Am. Corp., 299 F.3d 1313, 1331 (Fed. Cir. 2002) (quoting Young Dental Mfg. Co. v. Q3 Special Prods., Inc., 112 F.3d 1137, 1144 (Fed. Cir. 1997)).

that "[t]here is no requirement in 35 USC 112 that an applicant point out which of the embodiments he considers his best mode,"[31] but in dissent Judge Mayer called this "the antithesis of the good-faith full disclosure that is mandated by section 112's best mode requirement."[32] This requirement could be strengthened by holding that patentees must identify which example is the best mode, and perhaps by creating a duty to supplement the specification if a new best mode is discovered.[33]

It is striking (and surprising to many scientists) that an inventor can receive a patent without doing an experiment or building a model to see if her invention works the way she thinks it should. Satisfying the disclosure requirements of § 112 is treated as "constructive reduction to practice," a doctrine that is described by the leading patent law treatise as "a curious balance in terms of policy" because it "dispenses altogether with actual reduction to practice," which "has long been viewed as of primary importance in establishing the date of invention."[34] The Supreme Court has effectively accepted this doctrine: writing for a unanimous Court in *Pfaff v. Wells Electronics*, Justice Stevens noted that "[i]t is well settled that an invention may be patented before it is reduced to practice."[35] Sean Seymore has summarized the problems with constructive reduction to practice (and the resulting "prophetic examples"[36]) and argued that "at least for

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[31] Randomex, Inc. v. Scopus Corp., 849 F.2d 585, 589 (Fed. Cir. 1988).

[32] *Id.* at 591 (Mayer, J., dissenting). Donald Chisum notes that this decision may have been driven by the specific facts of the case, and says that "[t]ypically, drafters of patent specifications explicitly state that particular parameters are the preferred implementations." 3 DONALD S. CHISUM, CHISUM ON PATENTS § 7.05(f) (2010).

[33] Again, this would require a flexible interpretation of "new matter" in 35 U.S.C. § 132(a) (2006). *See supra* note 16 and accompanying text.

[34] 3A CHISUM, *supra* note 32, § 10.05.

[35] Pfaff v. Wells Elecs., Inc., 525 U.S. 55, 61 (1998). The Court held that an inventor who marketed his invention (a computer chip socket) over a year before submitting a patent application was barred from patenting his invention on novelty grounds, even though he had not reduced the invention to practice. *Id.* at 57-58, 68-69. For a thorough discussion of *Pfaff*, including the observation that the *Pfaff* Court never referenced 35 U.S.C. § 112, see Timothy R. Holbrook, *The More Things Change, the More They Stay the Same: Implications of* Pfaff v. Wells Electronics, Inc. *and the Quest for Predictability in the On-Sale Bar*, 15 BERKELEY TECH. L.J. 933, 969-71 (2000).

[36] *See* 3A CHISUM, *supra* note 32, § 10.05 Supp. ("Consistent with the doctrine of constructive reduction to practice, an applicant for a patent may include one or more 'prophetic' examples, that is, specific illustrations of the invention that have not, in fact, been carried out.").

complex inventions, an actual reduction to practice must become the standard of disclosure."[37]

The § 112 requirement that patented inventions be reproducible to a PHOSITA without undue experimentation are similar to the standards of scientific publication.[38] An editorial in *Nature Cell Biology* noted that "[a]n essential part of the process [of research] is that scientific papers are sufficiently detailed to allow for assessment of the data and for independent reproduction of experiments,"[39] and the *Nature* journals require authors to share data and materials so that others can "replicate and build upon the authors' published claims."[40] *Science* has a similar policy,[41] as do many other journals that publish data-driven results.[42] Federal grant agencies also impose disclosure requirements: the National Science Foundation (NSF) expects grant recipients to "promptly" publish their findings and to share "data, samples, physical collections and other supporting materials created or gathered in the course of work,"[43] and

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[37] Seymore, *supra* note 7, at 628-32, 641; *see also* Christopher A. Cotropia, *The Folly of Early Filing in Patent Law*, 61 HASTINGS L.J. 65, 119-128 (2009) (arguing that actual reduction to practice should be required to prevent problems with early patent filing); Michael Risch, *A Surprisingly Useful Requirement*, 19 GEO. MASON L. REV. (forthcoming 2011) (manuscript at 34-35), *available at* http://ssrn.com/abstract=1790463 (arguing that constructive reductions to practice that lack evidence of operability should be considered under utility, not disclosure).

[38] *Cf.* Joshua R. Nightingale, *The Researcher Rat's Culture and Ease of Access to the Publication Lever: Implications for the Patentability of University Scientific Research*, 113 W. VA. L. REV. 521, 541 (2011) ("Patent law's enablement requirement finds a close analogue in the peer review system's goal of determining the validity of data and conclusions presented.").

[39] Editorial, *Reproducibile Methods*, 11 NATURE CELL BIOLOGY 667, 667 (2009).

[40] *Editorial Policies: Availability of Data and Materials*, NATURE, http://www.nature.com/authors/editorial_policies/availability.html (last visited Dec. 21, 2010).

[41] *See General Information for Authors*, SCIENCE, http://www.sciencemag.org/site/feature/contribinfo/prep/gen_info.xhtml (last visited Dec. 21, 2010) (requiring authors to share "data necessary to . . . extend the conclusions of the manuscript" and to fulfill "all reasonable requests for materials").

[42] *See, e.g.*, *The* American Economic Review*: Data Availability Policy*, AM. ECON. ASS'N, http://www.aeaweb.org/aer/data.php (last visited Jan. 18, 2011); *see generally* Victoria Stodden et al., *Reproducible Research*, COMPUTING SCI. & ENGINEERING, Sept./Oct. 2010, at 8, 10-11 (giving other examples of journals that require authors to make their data and code publicly accessible).

[43] NAT'L SCI. FOUND., GENERAL GRANT CONDITIONS (GC-1), at 34 (2010), *available at* http://www.nsf.gov/pubs/gc1/oct10.pdf.

the National Institutes of Health (NIH) requires sharing to aid "the advance of further research."[44]

### B. Is Disclosure a Compelling Justification for Patents?

The patent system exists "[t]o promote the Progress of Science and useful Arts,"[45] and courts and commentators have almost uniformly embraced this utilitarian theory.[46] Utilitarian justifications for patents have been divided broadly into arguments that patents provide incentives for (1) innovation and (2) disclosure.[47]

Under innovation incentive theories, patents encourage new inventions by preventing appropriation by competitors, and we accept the deadweight loss caused by the exclusive patent grant (which can be substantial, depending on the elasticity of demand and the availability of substitutes) in exchange for an increase in innovation.[48] There is much theoretical confusion, however, about exactly how patents promote innovation. For example, the traditional reward theory states that patents reward ex ante investments in innovation,[49] while commercialization or prospect theory states that exclusive property rights are needed to encourage development *after* the patent

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[44] NAT'L INSTS. OF HEALTH, U.S. DEP'T OF HEALTH AND HUMAN SERVS., NIH GRANTS POLICY STATEMENT, at IIA-87 (2010), *available at* http://grants.nih.gov/grants/policy/nihgps_2010/nihgps_2010.pdf.

[45] U.S. CONST. art. I, § 8, cl. 8.

[46] *See, e.g.*, Aronson v. Quick Point Pencil Co., 440 U.S. 257, 262 (1979) (citing Kewanee Oil Co. v. Bicron Corp., 416 U.S. 470, 480-81 (1974)) (stating that the purposes of the patent system are (1) "to foster and reward invention," (2) to "promote[] disclosure of inventions," and (3) "to assure that ideas in the public domain remain there"); Graham v. John Deere Co., 383 U.S. 1, 9 (1966) ("The patent monopoly was not designed to secure to the inventor his natural right in his discoveries. Rather, it was a reward, an inducement, to bring forth new knowledge."); Dan L. Burk & Mark A. Lemley, *Policy Levers in Patent Law*, 89 VA. L. REV. 1575, 1597 (2003) ("To a greater extent than any other area of intellectual property, courts and commentators widely agree that the basic purpose of patent law is utilitarian . . . .").

[47] *See* Eisenberg, *supra* note 5, at 1024; Katherine J. Strandburg, *What Does the Public Get? Experimental Use and the Patent Bargain*, 2004 WIS. L. REV. 81, 104.

[48] For an overview of deadweight loss caused by patents, see F. SCOTT KIEFF ET AL., PRINCIPLES OF PATENT LAW 57-65 (4th ed. 2008).

[49] *See* MACHLUP REVIEW, *supra* note 5, at 33 (summarizing the reward theory and noting that it is "widely accepted"). A variation on reward theory is racing theory, under which the reward "is not the promise of a payoff, but the threat of being taxed or even excluded from the market if they lose the race." Lemley, *supra* note 5, at 63; *see* Michael Abramowicz, *The Uneasy Case for Patent Races over Auctions*, 60 STAN. L. REV. 803 (2007).

is granted.[50] Others have theorized that anticommons problems and patent thickets actually *hinder* innovation.[51]

Empirical support for any of these innovation theories is mixed, with a number of surveys indicating that outside the drug industry, patents are a less effective means of appropriation than secrecy or lead time.[52] James Bessen and Michael Meurer state that "we can safely conclude that during the late 1990s, the aggregate cost

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[50] *See generally* Edmund Kitch, *The Nature and Function of the Patent System*, 20 J.L. & ECON. 265 (1977) (introducing the new prospect theory of patents); John F. Duffy, *Rethinking the Prospect Theory of Patents*, 71 U. CHI. L. REV. 439, 445 (2004) (arguing that patent prospects maximize social benefits not by eliminating rivalry but by acting as "auctions for patent rights, with the winner being the competitor willing to provide the innovation to the public for the least rents"); Michael Abramowicz, *The Danger of Underdeveloped Patent Prospects*, 92 CORNELL L. REV. 1065 (2007) (arguing that early prospect patenting leads to undeveloped inventions).

[51] *See* Burk & Lemley, *supra* note 46, at 1624-30; Michael A. Heller & Rebecca S. Eisenberg, *Can Patents Deter Innovation? The Anticommons in Biomedical Research*, 280 SCIENCE 698 (1998).

[52] *See* Wesley M. Cohen, Richard R. Nelson & John P. Walsh, *Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)* 9 (Nat'l Bureau of Econ. Research, Working Paper No. 7552, 2000), *available at* http://www.nber.org/papers/w7552.pdf (surveying research and development managers and finding that "patents are unambiguously the least central of the major appropriability mechanisms overall" and that "in no industry are patents identified as the most effective appropriability mechanism"); Richard C. Levin et al., *Appropriating the Returns from Industrial Research and Development*, 1987 BROOKINGS PAPERS ON ECON. ACTIVITY 783, 796 (surveying industrial research managers and finding "limited effectiveness of patents as a means of appropriation"); Edwin Mansfield, *Patents and Innovation: An Empirical Study*, 32 MGMT. SCI. 173, 174 (1986) (surveying one hundred U.S. firms—excluding very small firms—and reporting that "patent protection was judged to be essential for the development or introduction of 30 percent or more of the inventions in only two industries—pharmaceuticals and chemicals"). Patenting may be more important for smaller firms. *See* Stuart J.H. Graham, *High Technology Entrepreneurs and the Patent System: Results of the 2008 Berkeley Patent Survey*, 24 BERKELEY TECH. L.J. 1255, 1262 (2010) (surveying early-stage technology companies and finding that patenting is "the most important appropriability strategy" among biotechnology firms and that patenting "was effective at protecting about one-half" of innovations in venture-backed IT hardware firms). In 1958, after arguing that reward theory was the most compelling justification for the patent system and reviewing its function in practice, Fritz Machlup famously concluded:

> If we did not have a patent system, it would be irresponsible, on the basis of our present knowledge of its economic consequences, to recommend instituting one. But since we have had a patent system for a long time, it would be irresponsible, on the basis of our present knowledge, to recommend abolishing it.

MACHLUP REVIEW, *supra* note 5, at 80. Our understanding of the economic effects of the patent system has not significantly improved in the past fifty years.

of patents exceeded the aggregate private benefits of patents for United States public firms outside the chemical and pharmaceutical industries," so that "patents very likely provided a net *dis*incentive for innovation."[53] Reports from the Federal Trade Commission and the National Academy of Sciences have expressed concern about patents increasingly hindering innovation and have recommended significant reform.[54] As noted by Nancy Gallini,

> Recent research has called into question . . . the effectiveness of patents as a tool for stimulating innovation. . . . Even if patents do not stimulate innovation, policies that promote strong patents may be justified. A second purpose of patents is to promote disclosure, a benefit that remains intact under the modern dynamic theory of patents.[55]

As discussed in the remainder of this Section, if patents provided no innovation incentive, I do not believe that the disclosure incentive alone would be sufficient to justify the patent system. But given that we do have an entrenched international patent system[56]—whether it promotes innovation or not—this Article will probe whether strong disclosure should be a central goal of that system.

Disclosure theory focuses on the quid pro quo of the patent system: the inventor receives the exclusive patent right in exchange for fully disclosing the invention to society, rather than keeping the invention secret (such as with trade secret protection).[57] The Supreme

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[53] JAMES BESSEN & MICHAEL J. MEURER, PATENT FAILURE: HOW JUDGES, BUREAUCRATS, AND LAWYERS PUT INNOVATORS AT RISK 141 (2008). *But see* Glynn S. Lunney, Jr., *On the Continuing Misuse of Event Studies: The Example of Bessen and Meurer*, 16 J. INTELL. PROP. L. 35, 54 (2008) (arguing that event studies "consistently overreact to certain kinds of unexpected bad news" in a way that "fatally undermine[s] Bessen and Meurer's ultimate conclusion that patents have become a net disincentive for most industries").

[54] *See* FED. TRADE COMM'N, TO PROMOTE INNOVATION: THE PROPER BALANCE OF COMPETITION AND PATENT LAW AND POLICY (2003), *available at* http://www.ftc.gov/os/2003/10/innovationrpt.pdf; NAT'L ACAD. OF SCIS., A PATENT SYSTEM FOR THE 21ST CENTURY (Stephen A. Merrill et al. eds., 2004), *available at* http://www.nap.edu/catalog.php?record_id=10976.

[55] Nancy T. Gallini, *The Economics of Patents: Lessons from Recent U.S. Patent Reform*, 16 J. ECON. PERSP. 131, 132 (2002).

[56] The United States is required to grant patents under both TRIPS, *supra* note 18, and the Paris Convention for the Protection of Industrial Property, Mar. 20, 1883, revised July 14, 1967, 21 U.S.T. 1583, 828 U.N.T.S. 305.

[57] *See, e.g.*, Gallini, *supra* note 55, at 132. An alternative line of scholarship, which might be considered a branch of disclosure theory, argues that patents are valuable not because they *require* disclosure in the patent, but because they *allow* disclosure

Court has often cited disclosure as one of the main purposes of the patent system.[58] Many patent law theorists, however, are more skeptical; as noted by Rebecca Eisenberg, "[t]he incentive to disclose argument . . . has been more popular with the courts than with commentators,"[59] although there have been some recent defenders.[60] Critics of disclosure theory argue that society receives little benefit in the quid pro quo exchange because (1) actual patents contain little valuable technical information, (2) willful infringement rules cause innovators to avoid reading patents, and (3) only inventions that

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outside the patent. Patents allow inventors to license their ideas to the most efficient manufacturers, *see* WILLIAM M. LANDES & RICHARD A. POSNER, THE ECONOMIC STRUCTURE OF INTELLECTUAL PROPERTY LAW 328-30 (2003), and they allow academically oriented scientists to satisfy their desire to publish while protecting the rights of their commercially oriented funders, *see* Joshua S. Gans, Fiona E. Murray & Scott Stern, Contracting over the Disclosure of Scientific Knowledge: Intellectual Property and Academic Publication 2-3 (April 8, 2011) (unpublished manuscript), *available at* http://ssrn.com/abstract=1559871. But these theories have little to say about the benefit of disclosure in the patent itself, and will thus not be explored in this Article.

[58] *See, e.g.*, Bilski v. Kappos, 130 S. Ct. 3218, 3252 (2010) ("[W]e interpret ambiguous patent laws as a set of rules that 'wee[d] out those inventions which would not be *disclosed* . . . but for the inducement of a patent,' . . . ." (quoting Graham v. John Deere Co., 383 U.S. 1, 11 (1966)) (second alteration in original) (emphasis added)); Eldred v. Ashcroft, 537 U.S. 186, 225 (2003) ("The issuance of a patent is appropriately regarded as a *quid pro quo*—the grant of a limited right for the inventor's disclosure and subsequent contribution to the public domain.") (citing Pfaff v. Wells Elecs., Inc., 525 U.S. 55, 63 (1998)); Festo Corp. v. Shoketsu Kinzoku Kogyo Kabushiki Co., 535 U.S. 722, 736 (2002) ("[E]xclusive patent rights are given in exchange for disclosing the invention to the public."); J.E.M. Ag Supply, Inc. v. Pioneer Hi-Bred Int'l, Inc., 534 U.S. 124, 142 (2001) ("The disclosure required by the Patent Act is 'the *quid pro quo* of the right to exclude.'" (quoting Kewanee Oil Co. v. Bicron Corp., 416 U.S. 470, 484 (1974)); Bonito Boats, Inc. v. Thunder Craft Boats, Inc., 489 U.S. 141, 151 (1989) ("'In consideration of [the invention's] disclosure and the consequent benefit to the community, the patent is granted.'") (quoting United States v. Dubilier Condenser Corp., 289 U.S. 178, 186 (1933)); *Kewanee Oil*, 416 U.S. at 481 ("[S]uch additions [from patent disclosures] to the general store of knowledge are of such importance to the public weal that the Federal Government is willing to pay the high price of . . . exclusive use."); Sinclair & Carroll Co. v. Interchemical Corp., 325 U.S. 327, 331 (1945) ("[The patent system's] inducement is directed to disclosure of advances in knowledge which will be beneficial to society . . . ."); Grant v. Raymond, 31 U.S. (6 Pet.) 218, 247 ("[A] correct specification . . . is necessary in order to give the public . . . the advantage for which the privilege is allowed, and is the foundation of the power to issue a patent.".

[59] Eisenberg, *supra* note 5, at 1028.

[60] *See supra* note 7 and accompanying text.

would be disclosed anyway are patented. I examine these arguments—and their counterarguments—in turn.[61]

The first critique of disclosure theory is that patents do *not* disclose useful information; rather, patent disclosures are often inadequate or opaque, or are more clearly described in other technical literature.[62] Even the Supreme Court, in a rare expression of skepticism about disclosure theory, has noted that "in light of the highly developed art of drafting patent claims so that they disclose as little useful information as possible—while broadening the scope of the claim as widely as possible—the argument based upon the virtue of disclosure must be warily evaluated."[63]

This Article evaluates the empirical validity of this critique. Anecdotal evidence calls this critique into question; for example, a patent attorney commenting on a previous paper of mine wrote, "[A] friend of mine who supplies complex chemicals to drug manufacturers . . . was delighted to find details of a drug component his customer was interested in—get this—in Google Patents. . . . [T]here remains a HUGE amount of readily available information in published patents and this benefits all scientists in the community."[64] But this Article

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[61] These critiques that patents do not (or should not) disclose information to future inventors are different from arguments that patents themselves block future innovation. For the challenges in designing a patent system to foster cumulative innovation, see, for example, Suzanne Scotchmer, *Standing on the Shoulders of Giants: Cumulative Research and the Patent Law*, J. ECON. PERSP., Winter 1991, at 29.

[62] *See* Devlin, *supra* note 5, at 403 ("The information conveyed by many specifications is inadequate and, in practice, fails to reflect the legislative requirements of § 112."); Lemley, *supra* note 5, at 50 ("[T]he fact that many of those patents obfuscate the technology at issue, deliberately or because we lack a clear language for communicating some types of inventions, means that the payoff from reading those applications is often dubious."); Roin, *supra* note 5, at 2025-26 (arguing that "[m]any patent inventions cannot be recreated or put into use based on the information in the patent itself," and that legal rules "create incentives for patent applicants to draft their disclosures opaquely").

[63] Brenner v. Manson, 383 U.S. 519, 534 (1966). Justice Fortas held that a process for making a chemical with "tumor-inhibiting effects in mice" did not meet the utility requirement of 35 U.S.C. § 101 because the patent did not demonstrate that "specific benefit exists in currently available form," and he made this statement to reject the argument that this narrowed definition of utility would limit the dissemination of new information. *Id.* at 531, 534-35. The Federal Circuit generally ignored this "high water mark" for utility and "lower[ed] the bar back toward the more lenient standards of utility espoused pre-*Manson*." JANICE M. MUELLER, AN INTRODUCTION TO PATENT LAW 159, 161 (2003).

[64] Joseph Page, Comment to *Access to Bio-Knowledge: From Gene Patents to Biomedical Materials*, STAN. TECH. L. REV. (Mar. 21, 2010, 10:54 AM), http://stlr.stanford.edu/2010/03/access-to-bio-knowledge/.

tackles the question more systematically: Section I.C examines previous surveys of the value of patent disclosures, which show that patents do provide useful information to at least some inventors, and Parts II and III present new survey evidence from nanotechnology researchers and case studies of specific nanotechnology patents. Even the defenders of disclosure theory have not grappled with the existing empirical evidence. Some commentators have simply assumed that patents perfectly disclose inventions,[65] while others agree that disclosure is currently poor but argue that the solution is to improve disclosure, not to abandon the theory.[66]

The second critique of disclosure theory is that even if patent disclosures are enlightening, inventors do not read them because of concerns about willful infringement.[67] The Patent Act allows courts to award treble damages and attorney fees,[68] and the Federal Circuit has held that enhanced damages may only be awarded in cases of willful infringement.[69] Under earlier interpretations of the willfulness

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[65] *See, e.g.*, Vincenzo Denicolò & Luigi Alberto Franzoni, *The Contract Theory of Patents*, 23 INT'L REV. L. & ECON. 365, 68 (2004); Ronald E. Myrick, William P. Skladony & Ram Nath, *The Technological Innovation Process: Patent Documentation as a Source of Technological Information*, 9 SANTA CLARA COMPUTER & HIGH TECH. L.J. 355, 357-59 (1993); Suzanne Scotchmer & Jerry Green, *Novelty and Disclosure in Patent Law*, 21 RAND J. ECON. 131, 134 (1990).

[66] *See* Fromer, *supra* note 7, at 563 (arguing that patents do not "do nearly enough to convey information useful to stimulate inventive activity" and explaining "how the patent document can be restructured to vitalize its relevance"); Seymore, *supra* note 7, at 626-27 (arguing that patents are often "indecipherable" or do not fully disclose inventions, and that "[i]t is now time to transform the patent into a readable teaching document").

[67] *See* Devlin, *supra* note 5, at 404 & n.16; Holbrook, *supra* note 5, at 142-43; Mark A. Lemley & Ragesh K. Tangri, *Ending Patent Law's Willfulness Game*, 18 BEREKELY TECH. L.J. 1085, 1100-02 (2003); Mark Lemley, *supra* note 5, at 50 ("[L]awyers often advise engineers not to read competitor patents for fear of becoming a willful infringer."); Doug Lichtman, *Substitutes for the Doctrine of Equivalents: A Response to Meurer and Nard*, 93 GEO. L.J. 2013, 2023 & n.42 (2005) (claiming that "very few people read patents outside of the litigation and licensing contexts" because "[t]he risks [of willful or contributory infringement] are just too high," and concluding that the "common misconception . . . that the patent system promotes disclosure and dissemination through the written patent document" is therefore "clearly not right"); Roin, *supra* note 5, at 2019-20 ("Faced with this calculation [of the risk of enhanced damages], many innovators have ceased using patents as a research tool . . . .").

[68] 35 U.S.C. § 284 (2006) ("[T]he court may increase the damages up to three times the amount found or assessed."); *Id.* § 285 ("The court in exceptional cases may award reasonable attorney fees to the prevailing party.").

[69] *See, e.g.*, *In re* Seagate Tech., LLC, 497 F.3d 1360, 1368 (Fed. Cir. 2007) (en banc). A finding of willful infringement is also sufficient to award attorney fees. *See*

doctrine, to avoid liability for enhanced damages, any company that learned of a potentially relevant patent had to spend $20,000 to $100,000 per patent for an attorney opinion stating that the patent is invalid or not infringed—leading many companies to advise researchers to avoid reading patents and to look elsewhere for technical information.[70]

Jeanne Fromer argues that "it is vital to remove—if not reverse—the penalty of willful infringement as applied to reviewing patents to inform follow-up innovation."[71] The Federal Circuit recently took a step in this direction by raising the standard for willful infringement from negligence to "at least . . . objective recklessness" and "reemphasiz[ing] that there is no affirmative obligation to obtain opinion of counsel."[72] Sean Seymore claims that this "suggests that simply reading a patent will not trigger the doctrine,"[73] although others believe the doctrine is unclear.[74] Research organizations can at least take some assurance from the former Federal Circuit Chief Judge Paul Michel: "People sometimes extrapolate wildly from what [a Federal Circuit] case actually held or even what the court said, other than perhaps in blatant dicta. The people who say, 'Don't read your rival company's patents because you'll get hung for willful infringement'—I think that's ridiculous."[75]

The survey evidence in Section II.E of this Article shows that nanotechnology researchers—both academic and industrial—are not avoiding reading patents because of legal concerns like willful infringement. In Section IV.B, however, I argue that rather than keeping legal rules that are widely ignored, the rules should be changed to match the norms and expectations of the scientific culture. Basic researchers should thus have a broader experimental use

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Knorr-Bremse Systeme Fuer Nutzfahrzeuge GmbH v. Dana Corp., 383 F.3d 1337, 1347 (Fed Cir. 2004) (en banc).

[70] *See* Lemley & Tangri, *supra* note 67, at 1092, 1100-01.

[71] Fromer, *supra* note 7, at 588. *See also* Lemley & Tangri, *supra* note 67, at 1125 (arguing that a "narrower willfulness doctrine" would "more faithfully serve the purposes of patent law").

[72] *Seagate*, 497 F.3d at 1371.

[73] *Seymore*, *supra* note 7, at 625.

[74] *See, e.g.*, Pan C. Lee, Note, *A Matter of Opinion: Opinions of Counsel Remain Necessary After* In re Seagate, 25 BERKELEY TECH. L.J. 33, 36 (2010) (describing the "unsure post-*Seagate* landscape").

[75] Paul Michel, Chief Judge, Fed. Circuit, Address at the Fordham University School of Law (Nov. 2009), *in Innovation, Incentives, Competition, and Patent Law Reform: Should Congress Fix the Patent Office and Leave Litigation Management to the Courts?*, 20 FORDHAM INTELL. PROP. MEDIA & ENT. L.J. 1135, 1168 (2010).

exemption and should not be threatened with enhanced damages for turning to the patent literature as a source of technical information.

Finally, the third, and most compelling, critique of disclosure theory is that patents are only sought on inventions that are relatively cheap to reverse engineer (generally referred to as "self-disclosing" inventions, although that phrase is misleading and imprecise) or that would soon be invented by others.[76] Under this theory, an inventor will only patent a "non-self-disclosing" (i.e., expensive to reverse engineer) invention (rather than protecting it with trade secrets[77]) if it seems likely that others will recreate the invention before the patent expires, so that "the invention was inevitably coming to the public regardless of the patent disclosure."[78]

A problem with this critique is that few inventions are "self-disclosing" at zero cost. Jeanne Fromer notes that "[e]ven when the information is sometimes available elsewhere, it is normally not available widely."[79] She argues that "[m]uch of the information contained in—or that ought to be in—patents is not published elsewhere," and that "it typically takes a long time after patent publication before the invention becomes available for theoretical reverse-engineering" (if the invention is commercialized at all).[80] Similarly, Alan Devlin notes that reverse engineering involves wasted expense and "may give rise to proprietary information that will only be shared indirectly with the public."[81] Denicolò and Franzoni also refute this critique through an economic model—although their

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[76] *See* MACHLUP REVIEW, *supra* note 5, at 32 (stating that economists "have shown considerable skepticism" of disclosure theory because of both "the unwillingness of firms to patent what they think they may be able to keep secret" and "the inability of manufacturers to keep secret most of the technology they use and, consequently, society's munificence in granting monopolies for the disclosure of what would become known in any case"); Devlin, *supra* note 5, at 418; Eisenberg, *supra* note 5, and 1028-29; Holbrook, *supra* note 5, at 132-35; Roin, *supra* note 5, at 2014-16.

[77] *See generally* Mark A. Lemley, *The Surprising Virtues of Treating Trade Secrets as IP Rights*, 61 STAN. L. REV. 311 (2008) (discussing the tradeoffs between patents and trade secrets); Michael Risch, *Trade Secret Law and Development Incentives*, *in* THE LAW AND THEORY OF TRADE SECRECY: A HANDBOOK OF CONTEMPORARY RESEARCH (Rochelle C. Dreyfuss et al. eds. 2011) (same).

[78] Holbrook, *supra* note 5, at 134-35.

[79] Fromer, *supra* note 7, at 554.

[80] *Id.* at 554, 558.

[81] Devlin, *supra* note 5, at 405. Devlin argues, however, that these benefits of disclosure are subsidiary to the innovation incentive. *Id.* at 406.

model assumes that patents perfectly disclose inventions to other innovators.[82]

This Article will show that patents do actually improve access to information, but I agree with the critics that disclosure is not a compelling *justification* for the patent system. Under a pure disclosure theory, one should consider an invention that *already exists* and ask whether we want to offer a patent (and its associated inefficiencies) in exchange for information about that invention. This bargain would only benefit the public for inventions that are unlikely to be independently discovered and are very costly to reverse engineer—in which case the inventor is likely to prefer trade secrecy over patents.

But whether or not disclosure justifies the patent system is moot because disclosure theory need not support the patent system on its own—the international patent system is not going away, and it probably does promote innovation, at least in some cases.[83] The more relevant question about disclosure is whether, given our existing system, we want to enforce robust disclosure requirements. Are the benefits of full disclosure underappreciated? Are current disclosure requirements being enforced? Are any legal changes necessary to make disclosures more useful to follow-on innovators? Would stronger disclosure requirements hurt innovation? These questions are addressed in Part IV, but first I examine the existing evidence about the utility of these disclosures as a source of technical information.

### C. Previous Surveys of the Value of Patent Disclosures

Both advocates of a strong disclosure function and those who believe disclosure should not be central to our patent system agree that patents currently do not disclose much useful information.[84] The empirical evidence cited by these sources, however, does not support this strong conclusion. Some of the cited evidence is anecdotal,[85] and

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[82] Denicolò & Franzoni, *supra* note 65, at 367-68.

[83] *See supra* note 56 and accompanying text.

[84] *Compare* Roin, *supra* note 5, at 2007, 2028 (claiming to present "a variety of evidence showing that the patent system largely fails at its disclosure function" and arguing that disclosure is not "the primary justification for the patent system"), *with* Fromer, *supra* note 7, at 560, 563 (agreeing that "there is evidence that most inventors spend little to no time reading others' patents to inform their research" but arguing that "patent disclosure is so important to the patent system's key purpose" that we should "invigorate disclosure"). For additional references, see *supra* note 8.

[85] For example, Benjamin Roin's note on disclosure theory cites individual testimony from the 2002 Federal Trade Commission (FTC) hearings on intellectual property. *See* Roin, *supra* note 5, at 2025 n.106 (describing conflicting evidence on whether engineers read patents). For transcripts from the FTC hearings, see

a few sources cite a model based on gross patenting data,[86] but most of the evidence comes from surveying people involved in research (though often not the innovators themselves) about the technical value of patent disclosures. This section reviews these surveys and concludes that, counter to the claims of legal commentators, many innovators are currently using patents as a source of useful technical information.

One of the most cited studies concerning the utility of patents as sources of technical information is a survey by Wesley Cohen and colleagues of managers of research and development units of U.S. manufacturing firms in 1994.[87] Mark Lemley cites it to support the claim that "[e]mpirical research suggests that scientists don't in fact gain much of their knowledge from patents, turning instead to other sources," and other scholars cite the study to support similar claims.[88]

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*Competition and Intellectual Property Law and Policy in the Knowledge-Based Economy*, FED. TRADE COMMISSION, http://www.ftc.gov/opp/intellect/ (last modified Sept. 28, 2007).

[86] *See* Ashish Arora, Marco Ceccagnoli & Wesley M. Cohen, *R&D and the Patent Premium* (Nat'l Bureau of Econ. Research, Working Paper No. 9431, 2003), *available at* http://www.nber.org/papers/w9431. Although this working paper is cited as showing that patent disclosures do not impact information flows between U.S. firms, *see* Fromer, *supra* note 7, at 562 n.110; Roin, *supra* note 5, at 2014 n.41, the paper notes that it is "unclear whether patent disclosures truly have little effect on the information flows from others that affect firms' R&D productivity, or whether the lack of an observable effect reflects that our measures are too imprecise to discern it," Arora et al., *supra*, at 17. This result is also deleted from the peer-reviewed version of this study. *See* Ashish Arora, Marco Ceccagnoli & Wesley M. Cohen, *R&D and the Patent Premium*, 26 INT'L J. INDUS. ORG. 1153 (2008). Other researchers have claimed that their models show that patents do not increase knowledge spillovers between firms. *See* James Bessen, *Patents and the Diffusion of Technical Information*, 86 ECON. LETTERS 121 (2005) (showing that in a simple theoretical model with complete information and no transaction costs, information diffusion is not necessarily greater under a patent system); Tobias Schmidt, *An Empirical Analysis of the Effects of Patents and Secrecy on Knowledge Spillovers* 16 tbl.1 (Zentrum für Europäische Wirtschaftsforschung GmbH, Discussion Paper No. 06-048, 2006), *available at* http://ssrn.com/abstract=920403 (modeling survey results to show a correlation between (1) reported "lack of information on technology" as a barrier to innovation and (2) reported "importance of patent protection" for a firm's industry). If these models are accurate, they provide support for my conclusion that disclosure theory alone is insufficient to justify the patent system. As noted earlier, however, rather than focusing on this broader question, I am taking the current patent system as a given and questioning whether strong disclosure should be a goal of that system. *See supra* Section I.B.

[87] Wesley M. Cohen et al., *R&D Spillovers, Patents and the Incentives to Innovate in Japan and the United States*, 31 RES. POL'Y 1349, 1350 (2002).

[88] Lemley, *supra* note 8, at 22 n.16; *see* Fromer, *supra* note 7, at 560 & n.101 (citing it to support the statement that "there is evidence that most inventors spend little to no time reading others' patents to inform their research"); Seymore, *supra*

But what the study actually found is that 49.1% of U.S. respondents indicated patents were "moderately" or "very" important as a source of information for a recent R&D project—less than the 61.8% who said the same of publications or the 51.3% for "informal exchange," but still almost half the sample.[89] Patents were the third most important information source, ahead of public meetings or conferences, competitors' products (via reverse engineering), joint or cooperative ventures, trade associations, recent hires, licenses, and contracts with other firms.[90]

Furthermore, Cohen and colleagues found that in Japan, patents were by far the most important information source for recently completed projects, with 85.4% of respondents ranking them as "moderately" or "very" important—significantly more than the 64.7% of respondents who said the same of publications, the next most important information source.[91] One of the Cohen study's authors, John Walsh, collaborated with Sadao Nagaoka to survey patentees in the U.S. and Japan in 2007.[92] They again found that Japanese firms "rely more heavily on the patent literature than do American firms," but they also determined that the Japanese firms were primarily reading U.S. patents, so that the difference was not caused by Japanese patents being more useful than U.S. patents.[93] (They do not discuss the language barrier, but most Japanese researchers are used to publishing and reading technical information in English.[94]) The results of these two surveys indicate that patents do currently serve a useful disclosure function for many innovators, including in the United States, and that Japanese researchers are finding even more useful information in U.S. patents than U.S.

note 7 (citing it for the proposition that patents "are not often viewed as an important channel for information flow"); Roin, *supra* note 5, at 2014 (citing it for the proposition that "U.S. firms most often use sources other than patent disclosures to learn about the most recent technological advances in their industry").

89 Cohen et al., *supra* note 87, at 1363 fig.6.

90 *Id.*

91 *Id.*

92 John P. Walsh & Sadao Nagaoka, *How "Open" Is Innovation in the US and Japan?: Evidence from the RIETI-Georgia Tech Inventor Survey* (Research Inst. of Econ., Trade & Indus., Discussion Paper No. 09-E-022, 2009), *available at* http://www.rieti.go.jp/jp/publications/dp/09e022.pdf.

93 *Id.* at 12-13.

94 *See* Robert S. Cutler, *A Comparison of Japanese and U.S. High-Technology Transfer Practices*, 36 IEEE TRANSACTIONS ON ENGINEERING MGMT. 17, 19 (1989) (surveying Japanese researchers in three high-technology fields and finding that ninety-four percent could read and write England and eighty-five percent published and read English language journals and articles).

researchers are—suggesting that the technical content of patents might be underexploited by U.S. researchers.

The 2003 survey of the Intellectual Property Owners Association (IPO) has been cited as "evidence that most inventors spend little to no time reading others' patents to inform their research" because it found that "65% of [respondents] do not always read patents before embarking on research, development, or product development."[95] But the 35% of respondents (primarily "senior legal staff"[96]) whose companies *always* read patents before beginning new research projects is still a substantial minority, and the number who *sometimes* read patents must be larger. Furthermore, the survey also found that patents are more important than publications as a source of technical ideas,[97] and that 64% of respondents routinely monitor their competitors' IP activity for technology ideas.[98]

Adam Jaffe and colleagues found that U.S. inventors who received patents in 1993 were not very familiar with patents cited in their patents.[99] But this does not reveal much about whether those cited patents contain useful technical information. More telling is their finding that patent citations do provide a statistically significant signal of knowledge "spillover"—i.e., that patentees are learning from roughly half the patents they cite.[100] The patentees were also asked what sources had a "significant influence" on the development of their invention: only about five percent of respondents indicated the patent literature, and only about 15 percent indicated the technical

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[95] Fromer, *supra* note 7, at 561 & n.104 (citing IAIN M. COCKBURN & REBECCA HENDERSON, SURVEY RESULTS FROM THE 2003 INTELLECTUAL PROPERTY OWNERS ASSOCIATION SURVEY ON STRATEGIC MANAGEMENT OF INTELLECTUAL PROPERTY, at F.6 (2003), *available at* http://www.ipo.org/AM/Template.cfm?Section=Home&Template=/CM/ContentDisplay.cfm&ContentID=8564).

[96] COCKBURN & HENDERSON, *supra* note 95, at A.1.

[97] *Id.* at D.1 ("Patent documents are rated more important than competitors, in-licensing, professional publications or government and university partnerships, and roughly equivalent to partnerships and joint ventures.").

[98] *Id.* at D.5. Other relevant statistics are that only 5% of respondents reported a negative impact from the earlier publication of patents at the application stage, 26% said that product lifecycles are typically shorter than the time for a patent to issue, and 75% thought that patents do not disclose too much valuable information to competitors. *Id.* at B.1, C.8, C.10.

[99] Adam B. Jaffe, Manuel Trajtenberg & Michael S. Fogarty, *The Meaning of Patent Citations*, *in* ADAM B. JAFFE & MANUEL TRAJTENBERG, PATENTS, CITATIONS, AND INNOVATIONS: A WINDOW ON THE KNOWLEDGE ECONOMY 379, 389 & fig.4, 390 & fig.5 (2002); *see also* Fromer, *supra* note 7, at 561 & nn.105-06 (citing the study for these points).

[100] Jaffe et al., *supra* note 99, at 394 & tbl.1, 400.

literature.[101] It is unclear why these responses differ so markedly from the earlier surveys discussed in this Section, but it may be because patentees view their work as novel (and thus may view prior work as informative but not a "significant influence") or because these respondents had less access to the patent and technical literature (both because the inventions were made in the pre-web 1980s and because the respondents were less likely to be professional scientists at large organizations). Still, despite their reported lack of interest in the patent literature, these 1993 patentees did obtain knowledge spillovers from other patents.

Other surveys have been conducted outside the United States. A 1997 survey of small and medium-sized companies in the United Kingdom found that 25.2% of companies searched the patent literature for technical reasons.[102] Follow-up interviews revealed that not knowing where to find patents and the cost of patent searches were significant barriers to access, and that the possibility of searching patents online "was greeted with considerable enthusiasm."[103] A different survey of small firms in the United Kingdom in 1996 found similar results for the number of firms doing technical patent searches.[104] An even earlier survey in Australia, conducted from 1980 to 1981, found that many respondents indicated that their main

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[101] *Id.* at 388 fig.3.

[102] *See* Matthew Hall, Charles Oppenheim & Margaret Sheen, *Barriers to the Use of Patent Information in UK Small and Medium-Sized Enterprises. Part I: Questionnaire Survey*, 25 J. INFO. SCI. 335, 339-40 (1999) (reporting that 56.4% of companies conduct patent searches, of which 40.7% do so for commercial and technical reasons, and 3.9% do so for technical reasons only).

[103] Matthew Hall, Charles Oppenheim & Margaret Sheen, *Barriers to the Use of Patent Information in UK Small and Medium-Sized Enterprises. Part 2 (1): Results of In-Depth Interviews*, 26 J. INFO. SCI. 87, 94 (2000).

[104] *See* Stuart Macdonald, *Bearing the Burden: Small Firms and the Patent System*, J. INFO. L. & TECH., July 2003, http://www2.warwick.ac.uk/fac/soc/law/elj/jilt/2003_1/macdonald (finding that "[a]bout half of these small firms regularly conduct patent searches," of which over 40% of patenting firms and 20% of non-patenting firms do so to keep abreast of technological developments, and that firms also looked to patents to avoid duplicating research, to acquire info to solve problems, to uncover new products, and (in very small numbers) to stimulate creativity). Another survey in the United Kingdom found that 18% of users of the British Library Patent Information Centre in 2000 cited finding technical information as their main reason for reading patents, and that the percentage was higher among those using patents every one to six months (rather than multiple times a month). David Newton, *A Survey of Users of the New British Library Patent Information Centre*, 22 WORLD PAT. INFO. 317, 321 & fig.3 (2000). But since many respondents were patent attorneys or professional patent searchers, it is unclear what this reveals about patent use by researchers.

reason for consulting patents was technical: the percentages ranged from 32% for small companies to 61% for respondents in higher education.[105]

Overall, the survey results discussed in this section show that even before patents became readily accessible through web searches, patents were a useful source of information for large numbers (though probably not the majority) of innovators. One would expect them to become more useful as they have become more accessible.

## II. Utility of Patents for Nanotech Researchers

As described in the previous Section, existing evidence suggests that many researchers do use patents as a source of technical information. Most of the earlier surveys are ten to twenty years old, predating the ready availability of patents online. The earlier surveys also focused either on managers and legal officers at technical companies or on patentees, and thus might not reflect the view of typical researchers.[106]

This Part adds to this empirical evidence with a survey of nanotechnology researchers that focused specifically on patent disclosures. Nanotechnology is the interdisciplinary study of systems on the nanometer scale,[107] and it has many potential applications: "Science and technology research in nanotechnology promises breakthroughs in areas such as materials and manufacturing, nanoelectronics, medicine and healthcare, energy, biotechnology, information technology, and national security. It is widely felt that nanotechnology will be the next Industrial Revolution."[108] Although

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[105] *See* Thomas Mandeville, *Australian Use of Patent Information*, 5 WORLD PAT. INFO. 79, 80 tbl.1 (1983) (reporting that 42% of large companies, 37% of medium companies, 32% of small companies, 53% of government respondents, 61% of higher education respondents, and 38% of individual engineers reported that their main reason for consulting patent information was to assess the state of the art, to consider new products, or to solve technical problems). Note that respondents could only check one option, so respondents whose secondary reason for consulting patents is technical are not included.

[106] The only survey that interviewed researchers who were not patentees was Mandeville's study, which surveyed professional engineers in Australia in 1980-81, though it did not indicate the response rate or many details about the survey. *See id.*

[107] It is hard to fathom how small a nanometer (a billionth of a meter) is. If you zoomed in so that a nanometer was as big as the diameter of one of your hairs, then your head would be roughly 10 miles in diameter.

[108] Bharat Bhushan, *Introduction to Nanotechnology*, *in* SPRINGER HANDBOOK OF NANOTECHNOLOGY 1, 1 (Bharat Bhushan ed., 3d ed. 2010).

nanotechnology is still an early-stage technology, nanotech patents have proliferated, raising concerns about a nanotech patent thicket.[109] Mark Lemley has argued, however, that "it does not seem appropriate at this early stage to restrict upstream nanotech patenting."[110]

The problems (or lack thereof) associated with the emerging nanotechnology patent thicket are beyond the scope of this Article. For my purposes, the relevant point is that there is an extensive nanotechnology patent literature, but that most nanotechnology researchers are academics or basic researchers who generally do not have to rely on patents because most advances are published in scientific articles. Because nanotechnology is still an exciting new field, it is easy for nanotech researchers to find scientific journals that will publish their work, and there are high-impact nanotechnology specialist journals like *Nano Letters* and *Nature Nanotechnology* that help researchers keep abreast of the field. One would therefore expect patents to be less useful to nanotech researchers than to more applied industrial researchers, though it would be interesting to replicate this survey in other settings.[111]

This Part presents the results from my survey of nanotech researchers. Section II.A describes the survey method and some basic summary statistics. Section II.B explains why the respondents choose to read patents (or choose to avoid them). Section II.C presents results on whether the researchers find useful technical information in the patents they read. Section II.D describes whether respondents feel that most patents are reproducible by a skilled researcher. Finally,

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[109] *See, e.g.*, Raj Bawa, *Nanotechnology Patent Proliferation and the Crisis at the U.S. Patent Office*, 17 ALB. L.J. SCI. & TECH. 699, 701 (2007) ("One of the major hurdles [in nanotechnology commercialization] is an emerging thicket of patent claims . . . ."); J. Peter Paredes, *Written Description Requirement in Nanotechnology: Clearing a Patent Thicket?*, 88 J. PAT. & TRADEMARK OFF. SOC'Y 489 (2006). A patent thicket occurs when overlapping patent rights cover a single technology, requiring commercializers to negotiate licenses with multiple rightsholders. *See generally* Carl Shapiro, *Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard Setting*, *in* 1 INNOVATION POLICY AND THE ECONOMY 119 (Adam B. Jaffe et al. eds., 2001), available at http://faculty.haas.berkeley.edu/shapiro/thicket.pdf.

[110] Mark A. Lemley, *Patenting Nanotechnology*, 58 STAN. L. REV. 601, 628 (2005).

[111] One might be concerned that because many nanotechnology researchers are academics, they might be more likely to read patents because they are less concerned about willful infringement—but my survey found that even industry researchers did not avoid patents for this reason. *See infra* Section II.E. Another concern is that nanotech patent disclosures might be better than in other fields because the appropriate level of disclosure has not been established. Even if these results cannot be generalized to fields like business methods, it is still important that patents disclose useful information in at least some fields.

Section II.E presents results about whether researchers avoid reading patents because of concerns about willful infringement.

The quotations provided throughout this Part are representative,[112] and the data in this Part (and in the supplementary tables in the Appendix) are presented separately from the analysis (which is generally saved for Part IV).

### A. Survey Method and Summary Statistics

I developed and conducted the survey to determine how nanotechnology researchers use patents as a source of technical information.[113] I emailed the survey in October 2010 to 1078 researchers who were listed as the corresponding authors on high-impact nanotechnology publications or who were listed on corporate nanotechnology research websites.[114] I received responses from 214 researchers by December 2010, giving a response rate of twenty percent; the representativeness of the respondents is explored below. Three respondents were eliminated from the data presented here because they did not have degrees in the natural sciences, so the following percentages are calculated out of 211.[115]

All the tables of results are displayed in the Appendix. Table 1 shows detailed statistics for the respondents, which are briefly summarized here. Most respondents work in academic labs (76%); a smaller number work in government labs (13%) or industry (8%). Most respondents are experimentalists (90%), not theorists (10%), and

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[112] I grouped the comments by topic and report a few from each topic.

[113] The survey is online. NANOTECHNOLOGY PAT. SURV., https://spreadsheets.google.com/viewform?formkey=dFpZeHJrbERqaU5ObHJlQU5XT1pFYnc6MA (last visited Dec. 14, 2010).

[114] The email addresses for corresponding authors in the ISI Web of Knowledge database were recorded for (1) articles in *Nature* or *Science* since 2006 with "nano* OR graphene OR 'single molecule'" in the title (293 addresses, after ignoring articles that were not related to nanotechnology); (2) articles in *Nature Nanotechnology* since 2006 (496 addresses); (3) articles in *Nano Letters* since 2009 with U.S. authors (835 addresses). *See* ISI WEB OF KNOWLEDGE, http://apps.isiknowledge.com/ (last visited Oct. 29, 2010). Eliminating duplicate or defunct email addresses resulted in 1057 addresses for corresponding authors. To increase the number of respondents from industry, an additional 21 nanotechnology researchers whose email addresses were listed on corporate research websites were also contacted, for a total of 1078 surveys distributed. Respondents were not offered any reward.

[115] Two are academics with Ph.D.s in anthropology and political science. The third has a bachelor's degree in business, works in industry, and claimed to have read approximately 500 patents over the past year, mostly to gain "competitive intelligence" about other companies.

far more characterized their research as basic (49%) than applied (15%) (with the rest doing an equal mix of basic and applied).[116]

The most common departments in which respondents received their Ph.D. were physics or applied physics (46%) or chemistry or biochemistry (22%); only 2% of respondents indicated that they do not have a Ph.D. or other doctoral degree. Most respondents received their highest degree in the 1990s (36%) or 2000s (40%); the oldest respondents received their degree in the 1960s (4%). Only 10% of respondents were female (4% did not indicate their gender). About a quarter (24%) of respondents work outside the United States.

With a twenty percent response rate (which is on the low end but within the range of response rates to other patent-related surveys of individual researchers[117]), one always needs to be concerned that the respondent sample might not be representative of the larger population. To look for response bias, Table 2 compares the 211 respondents with a random sub-sample of 100 researchers out of the 1078 researchers contacted.[118] The only statistically significant

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[116] Basic research focuses on fundamental principles, whereas applied research focuses on specific applications. Both experimental and theoretical research can be either basic or applied, although no respondents characterized their work as both theoretical and applied.

[117] *See* STEPHEN A. HANSEN, AM. ASS'N FOR THE ADVANCEMENT OF SCI., INTERNATIONAL INTELLECTUAL PROPERTY EXPERIENCES: A REPORT OF FOUR COUNTRIES 7-8 (2007), *available at* http://sippi.aaas.org/Pubs/SIPPI_Four_Country_Report.pdf (reporting response rates of 19% from Japanese scientists and approximately 16% from U.K. scientists for a web-based survey); STEPHEN A. HANSEN ET AL., AM. ASS'N FOR THE ADVANCEMENT OF SCI., INTELLECTUAL PROPERTY EXPERIENCES IN THE UNITED STATES SCIENTIFIC COMMUNITY 59 (2007), *available at* http://sippi.aaas.org/Pubs/SIPPI_US_IP_Survey.pdf (reporting a response rate of 27% from U.S. scientists for the same web-based survey); Zhen Lei, Rakhi Juneja & Brian D. Wright, *Patents Versus Patenting: Implications of Intellectual Property Protection for Biological Research*, 27 NATURE BIOTECHNOLOGY 36, 36 (2009) (reporting a response of 25% to a post-mail survey of agricultural biology faculty); John P. Walsh, Wesley M. Cohen & Charlene Cho, *Where Excludability Matters: Material Versus Intellectual Property in Academic Biomedical Research*, 36 RES. POL'Y 1184, 1186 (2007) (reporting a responses rates of 40% and 34% for two samples of academic biomedical researchers who were sent a post-mail survey).

[118] The current affiliation and gender of each researcher were determined through a web search. The number of papers from the previous two years was determined by searching for last name and first initial in ISI Web of Knowledge; affiliation was used to narrow the results for common names. *See* ISI WEB OF KNOWLEDGE, *supra* note 116. The number of patents submitted in the past two years could not be directly compared because patents are not published until eighteen months after submission, so the number of patents published in the past two years was used instead. This was determined by searching the PTO patent

difference between the respondents and the random sample is in the number of peer-reviewed papers published in the past two years: the survey respondents do not include the scientists who get their names on the highest number of papers. This discrepancy may be because those scientists are both very busy managing their large labs and are more likely to be writing in multiple fields (and thus less likely to be interested in a survey pitched to nanotechnology researchers).[119] There is no significant correlation between the number of published papers and whether a researcher reads patents, wants patents, thinks patents are useful, or thinks patents are enabled, so this bias should not affect the other results in this section. But it is worth noting that the respondents are not perfectly representative in this aspect.

On average, respondents have published fourteen papers and submitted two U.S. patents in the past two years. The first two columns of Table 5 contain regression coefficients, which illustrate how the number of papers and patents vary across different types of respondents.[120] Looking at coefficients that are statistically significant at least at the ten percent level shows that industry researchers and women tend to have fewer published papers, while older researchers

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application database for full names; state or country was used to narrow the results for common names. *See Patent Application Full Text and Image Database*, U.S. PAT. & TRADEMARK OFF., http://appft.uspto.gov/netahtml/PTO/search-adv.html (last visited Dec. 17, 2010). For use of a similar method to measure response bias in a patent survey of biomedical researchers, see Walsh et al., *supra* note 117, at 1186 n.6, 1201 tbl.A1.

[119] The most prolific scientist in my random sub-sample was Klaus Müllen, a director of the Max-Planck Institute for Polymer Research. Because his name goes on almost every paper from his over-eighty-person lab, he had 154 publications in 2009 and 2010. *See Publications of the Müllen Group*, MAX PLANCK INST. FOR POLYMER RES., http://www.mpip-mainz.mpg.de/groups/muellen/Publications (last updated Jan. 13, 2011). Only a few of those publications focus on traditional nanotechnology subfields; Dr. Müllen is more likely to consider himself a synthetic chemist than a nanotechnology researcher.

[120] Regressions allow you to see how different variables are correlated, controlling for other variables. For example, the first coefficient in Table 5 is negative (-0.34), which means that industrial researchers tend to have fewer papers than the average respondent. This coefficient also has one asterisk, which indicates that it is statistically significant at the ten percent level: there is only a ten percent chance that there is *not* a negative correlation between working in industry and the number of papers published. For an overview of regressions, statistical significance, and other basic statistical tools written for federal judges, see David H. Kaye & David A. Freedman, *Reference Guide on Statistics*, in FED. JUDICIAL CTR., REFERENCE MANUAL ON SCIENTIFIC EVIDENCE 83 (2d ed. 2000). The coefficients in the first two columns of Table 5 are based on quasi-maximum likelihood Poisson regressions because the dependent variables (the number of papers and patents) are nonnegative count variables. Coded data is available in Stata format upon request.

and those outside the United States tend to have more.[121] The second column shows that basic researchers and those outside the United States tend to have fewer patents, while industry researchers, experimentalists, and older researchers tend to have more.

Table 1 also shows that although 86 respondents (41%) have not had a patent submitted on their behalf in the past two years, almost all respondents (92%) indicated that if they discover patentable inventions in the future, they would like to have patents on them. The third column of Table 5 illustrates that basic researchers and physicists are less likely to want patents, while older researchers are more likely to want patents.[122]

Finally, Table 1 shows that 135 respondents (64%) have read at least some of a patent (other than their own) for a research purpose,[123] and the fourth regression in Table 5 shows that reading patents is less common among basic researchers and more common among industry researchers, experimentalists, and chemists. Respondents were directed to separate follow-up questions based on whether they have or have not previously read patents.

### B. Why Do Scientists Read Patents (or Not)?

The minority (36%) of researchers who have *not* read a patent were asked why, and Table 3 summarizes these responses. The most common response, checked by 86% of these patent-avoiding researchers, was "I do not think patents contain information that would be useful to me." A significant number (29%) also indicated that they do not know how to find relevant patents. Of the seventeen respondents (22%) who gave other reasons, five complained about "unreadable" or "obscurified" language, five expressed skepticism about the "quality of science" in patents, and two suggested that patents are duplicative of journal publications, which are "more informative."

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[121] "Older" is shorthand for respondents who completed their Ph.D. or other highest degree longer ago. The two are highly correlated, but the survey collected time since Ph.D. to measure more accurately what stage respondents were at in their professional careers.

[122] The coefficients in the last four columns of Table 5 are based on logistic regressions because the dependent variables are dummy variables. Linear regressions produce very similar results.

[123] I did not ask whether these were granted patents or patent applications because the scientists I consulted about my survey design did not know which they were reading.

The patent-avoiding researchers were also asked to explain which of their reasons for not reading patents is the most significant. Some responses indicated that the respondents had at least seen patents in the past; other respondents just gave their general impressions, which may reflect scientists' stereotypes of patents—one researcher candidly admitted, "I have not looked into any of these assumptions . . . and could be entirely incorrect." Six concerns about patents emerged from the responses, with respondents arguing that patents are (1) confusingly written; (2) unreliable; (3) duplicative of journal articles; (4) out of date; (5) difficult to find; and (6) in conflict with the open culture of science. These concerns are elaborated below.

First, the largest number of complaints involved the style in which patents are written—patents were called "vague," "legal jargon," "incomprehensible," and lacking "technical detail." A number of respondents expressed sentiments similar to this industry researcher:

> Patents contain too little useful information compared with the time it would take to extract it. They are written by people who are not interested in sharing, and they are not designed to be useful for other researchers. There may be many pages of boilerplate hiding the useful parts. . . . Another problem is the legal language used to write patents. As far as I can tell the main purpose of having this special language is to ensure that lawyers are needed to generate it.

Second, some respondents viewed patents as unreliable because of the lack of peer review. One nonprofit researcher wrote that "[p]atenting is not as scientifically rigorous as peer-reviewed papers," and a government researcher called patents "garbage" and said they "provide no guidance of what really has been or what really could be done." An academic from materials science wrote: "I have read patents describing results in my area that I know to be completely wrong, that don't cite the literature appropriately and that make little effort to be rigorous. This makes me pretty nervous about other patents where I am less expert in the results."

Third, some respondents thought that even if there is useful information in patents, it is duplicative of the scientific literature. For example, an academic physicist wrote, "Since the number of citations of patents in academic journals is vanishingly small it is evident that there is not information in them relevant to academic research that is not available elsewhere."[124]

Fourth, the timeliness of information in patents was also a concern for a number of respondents. Patents were described as "out of date," "behind the state of art technology," and "released too late for cutting edge research." An academic in electrical engineering wrote that "patents become public so long after the idea is conceived [that] the information in them is no longer really that important scientifically by the time they come out." Another electrical engineer working at a nonprofit said that patents will only be "relevant for research" when they are as "timely" as publications.

Fifth, some respondents said that patents are hard to find, with comments that patents are "not indexed by the scientific databases" or that the researcher "wouldn't know where to find patents." One academic biomedical researcher wrote that "[w]hile [G]oogle brings up patents, it is really hard to find the whole patent," and an academic physicist suggested that "[i]f patents were searchable by ISI along with journals, it might be worth taking a look." A physicist working in a government lab wrote: "If patent information was as easy to access as the scientific literature, and searching it were possible with something equivalent to [ISI] Web of Science, I would certainly read patents relevant to my work."

Sixth, and finally, some respondents questioned the role of patents in the open scientific culture, suggesting that "a strong focus on a patenting culture in academia can impede, rather than enhance, innovation." One foreign academic said that patents did not fit with his "naive and idealistic way of sharing science." A government physicist working in computation said that the "intellectual leaders" in his field "most frequently disseminate information in 'open source' format." And another physicist wrote: "As a publicly funded academic, a key part of my 'social contract' . . . is to make results from my research publicly available." A third physicist summarized the problem as follows: "In my opinion patents are generally a hindrance to our research as they motivate researchers to withhold publication of potentially important results until legal protection is achieved. This is largely counter to the spirit of academic research as it favors secrecy over sharing of information."[125]

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[124] For more concrete details about the citation of patents by scientific papers, see *infra* notes 251-253 and accompanying text.

[125] Convincing these respondents to turn to the patent literature for technical information would probably require more than better disclosure rules—it would require a fundamental change in the way academic research is patented.

The patent-avoiding respondents were also asked if they thought reading a patent later in their careers might be useful, and forty-seven percent said yes. Many respondents indicated that they would read patents for legal reasons, such as to see if their research is patentable. But others said they would look to the technical content of patents to learn about research "that was patented and not published as a research paper" or if they switched research directions to "an area in which patents would be relevant." A number of respondents also indicated that they would read patents for their technical content if changes were made, such as "[i]f it was easier to search for patents' scientific content." One theorist said he would read a patent if it were peer-reviewed and if the "findings [were] presented in a standard scientific format" that was "straightforward" and "easy to read."

Table 4 summarizes the responses from the 135 researchers who indicated that they *have* read a patent. These researchers were asked to check all of the ways in which they have found a patent. The most common methods were searching on the PTO website (60% of those who read patents)[126] and searching using Google Patents (45%),[127] but many researchers also received patents from someone in a legal department (38%), from other researchers (33%), or from citations (27%),[128] and 29% stumbled upon a patent during another search, which often happens now that Google displays patent results for many searches.[129] Only 8% of patent readers found patents using a different method; responses included WIPO's patent search,[130]

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[126] *USPTO Patent Full-Text and Image Database*, U.S. PAT. & TRADEMARK OFF., http://patft.uspto.gov/netahtml/PTO/search-adv.htm (last visited Dec. 15, 2010).

[127] Google introduced patent searches in December 2006. *See* Dennis Crouch, *Search Patents Via Google*, PATENTLYO (Dec. 14, 2006, 10:13 PM), http://www.patentlyo.com/patent/2006/12/search_patents_.html (describing *Google Patents*, GOOGLE, http://www.google.com/patents (last visited Dec. 15, 2010)). One can create an RSS feed in Google Patents by searching for a topic and clicking the "Stay up to date on these results using the patents RSS feed" link at the bottom. *See Google Patents*, *supra*.

[128] The survey did not ask respondents to specify the type of publication in which they found the citation (they simply checked "I found a citation to it in a paper or publication."), but given the relatively low number of citations to patents in technical publications, *see infra* notes 251-253 and accompanying text, many were probably citations from other patents.

[129] Patent results are also displayed when a researcher looks for scientific literature using Google Scholar, and after searching for a topic the "Create email alert" link can be used to get email updates about new patents or papers. *See Google Scholar*, GOOGLE, http://scholar.google.com (last visited Dec. 15, 2010).

[130] *Patentscope*, WIPO, http://www.wipo.int/pctdb/en (last visited Dec. 15, 2010).

esp@cenet (the EPO patent search database),[131] PATSTAT (an EPO statistical database of patents),[132] the Derwent Innovations Index (part of the ISI Web of Knowledge platform),[133] and the Chemical Abstracts Service.[134]

The respondents also indicated all of the reasons for which they have read a patent. The most common reason, indicated by 62% of respondents who have read a patent, was to determine whether their research was patentable. But a combined 70% of patent-reading respondents (45% of the entire sample) indicated that they have looked to patents for technical information: 40% wanted to see how other researchers solved a particular technical problem, 44% wanted to research a general scientific topic, and 16% wanted to browse information about cutting-edge technologies.[135] The following two Sections examine whether these respondents actually found useful technical information in the patents they read, and whether they considered the patents to be enabled.

### C. Do Patents Contain Useful Technical Information?

Sixty percent of respondents who looked to patents for technical information indicated that they found useful information there.[136] The researchers were not asked to name the specific patents they looked at, but given the diversity of their research fields, it is highly unlikely that they were turning to the same few patents. The regression in the fifth column of Table 5 shows that older respondents

[131] ESPACENET, http://ep.espacenet.com/ (last visited Dec. 15, 2010).

[132] *EPO Worldwide Patent Statistical Database*, EPO, http://www.epo.org/patents/patent-information/raw-data/test/product-14-24.html (last visited Dec. 15, 2010).

[133] Training materials for the Derwent Innovations Index, and a link for registered customers to access the database, are available at *Intellectual Property Solutions*, THOMSON REUTERS, http://ip.thomsonreuters.com/training/dii/ (last visited Dec. 15, 2010).

[134] Chemical Abstracts Service is a division of the American Chemical Society, and it "covers patents from around the world." *CAS Coverage of Patents*, CAS, http://www.cas.org/expertise/cascontent/caplus/patcoverage/index.html (last updated Oct. 20, 2010).

[135] The individual percents add up to more than 70% because some researchers selected more than one of these options.

[136] Patent-reading respondents were asked: "If you have read a patent to gain scientific knowledge (either applied to a particular problem or regarding a general research topic), did you find useful information there?" Sixty-four said yes; forty-three said no.

were more likely to find patents useful; none of the other variables were statistically significant.

When asked to elaborate, the respondents who had found useful information primarily cited "useful technical detail" like "clever descriptions and useful recipes." For example, one academic physicist wrote: "I will sometimes look at patents to see how a particular device works. Almost always some piece of lab equipment."[137] A chemist who works in an academic lab and for a startup wrote: "'Useful' doesn't mean 'insightful' or 'detailed' but it certainly was useful. The data helped put the ideas and research in context and offered some plausible views as to what we were seeing in our own research." Another chemist, work works in industry, explained: "Patents are a useful source of information on how others have approached particular technical problems and can also help you from going down a road that has already been traveled."

Some respondents found information in patents that was unavailable in scientific journal articles. For example, an academic electrical engineer wrote: "Practice details appear in patents by industry which do not get publish[ed] in the usual scientific literature." Another academic expressed the same sentiment: "A paper may contain less details about implementation than a patent in many cases. . . . So if I wanted to see how someone solved a technical issue, I would go through the patent." An academic chemist specified that "protocols or 'recipes' for preparing samples or performing experiments are described that are not found in other published literature." An industry researcher speculated about why this might be true:

> Usually the way a new technology is described is much more reliable and reproducible in a patent than in a scientific paper. Unfortunately many academic researchers purposely remove essential steps for reproducing data, for fear other researchers will catch up with them and publish first. In patents, on the other hand, there are more stringent requirements about

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[137] Note that it is not possible to tell whether the "lab equipment" was the patented invention itself or simply ancillary equipment that is related to the invention. In either case, the patent is providing useful technical information, and the proposals in Part IV (like peer review or an obligation to respond to questions about reproducibility) likely would improve the quality of both types of disclosures, as clear information about ancillary equipment would improve reproducibility. I thank Jeanne Fromer for this point.

> reduction to practice, so I trust patents more when I need to try other people's technologies.

A less rosy picture of the value of patents as technical sources was painted by the forty percent of researchers who said they did not find useful technical information there. These respondents echoed the first four of the six general complaints about patents described in Section II.B: patents are (1) confusingly written ("the language of patents is obscure"); (2) unreliable (patents do not "go through the same level of critical review that scientific articles face"); (3) duplicative of journal articles ("[t]here was no information in the patent that had not already appeared in the scientific literature"); and (4) out of date ("[t]he long time delay between filing an invention disclosure and the public issuance of a patent seems to make it very unlikely that patents will regularly be a useful source of research information in a field as rapidly moving as nanotechnology"). One academic chemist wrote: "[P]atents are often written to prevent people [from] being able to follow the scientific procedure. To a scientist the patent literature looks like an invention of lawyers for the benefit of other patent lawyers."

### D. Are Patents Reproducible?

Although sixty percent of researchers who look for technical information find some useful information, only thirty-eight percent of patent-reading researchers responded "yes" to a question about whether patents are reproducible: "Were the patents you read worded in such a way that you or another nanotech researcher could recreate the invention without additional information?"[138] And the percentage who think *all* the patents they read are reproducible is even lower because many researchers who said "yes" then qualified their answer with "sometimes" when asked to explain. The regression in the last column in Table 5 shows that industry researchers are more likely to think patents are reproducible, and that chemists are less likely.

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[138] As noted previously, some of these "patents" may have been patent applications, since scientists often do not know which they are reading. *See supra* note 123 and accompanying text. But seventy-seven to ninety-five percent of these specifications will end up in granted patents (when you include continuing applications, which must use the same specification to maintain the earlier priority date), *see* Cecil D. Quillen, Jr. & Ogden H. Webster, *Continuing Patent Applications and the U.S. Patent and Trademark Office—Updated*, 15 FED. CIR. B.J. 635, 661 (2006), and there is no reason to think that respondents were selectively reading patent applications that would be rejected for insufficient disclosure, so this does not affect my conclusion that this result raises serious questions about whether the disclosure requirements are being met for nanotechnology patents.

Of the researchers who responded "yes" and then provided additional comments, none were enthusiastic about the ease of reproducing inventions. The most positive comments stated that reproduction was possible once you got past the language: one respondent said that "[o]ften patents are impenetrable, but often the front matter (not the claims) give enough details that one can understand the method," and another wrote that "[i]t is possible, but it required efforts to understand [the] language" and that it "gets easier with time." An academic in mechanical engineering qualified his "yes" as follows:

> But it made you want to pull your teeth. The language is almost purposely abstruse. The figure and figure captions seem to be from a different era. The format of the patents is deplorable—for instance, figures are given early on and the description is usually 10 pages away. Even technical publications from [the] 1800s (an[d] I have read a few) are easier to read! But with difficulty, you can understand most of the patent.

Others indicated that they could only hypothesize about reproducibility: an academic physicist said that she "never actually tried to reproduce" but that she "for the most part . . . found all the critical aspects explained," and a different academic physicist responded: "Never tried to recreate a highly technical one. Most are, once disclosed, technologically obvious."

A few researchers had a particularly skeptical "yes," with comments that a patent is "more vague than a scientific paper" and that "at times the patents required proprietary materials that were not available or clearly left out stages that needed to be re-created." One industry physicist said patents are "mostly" reproducible, but "many nanotechnology patents have not been reduced to practice" and are "completely impossible" but "just try to claim some param[e]ter space on the hopes that some future work will get covered."

Even harsher criticisms of patents were leveled by those who responded "no" to the reproducibility question. Two respondents wrote that "the devil is in the details," which most respondents believe are missing from the patents. One complained that patents "do not contain the subtle tricks and procedures that enable the invention to be reproduced," and another wrote: "We have tried to reproduce the odd result in a patent, but often additional details are needed that have been left out (on purpose)."

A number of respondents echoed this concern that details were deliberately omitted by the patentees, with comments that patents are "worded to confuse rather than to educate" and are "very vague—deliberately so(?)—in detail." Reproducibility is not identical to the legal enablement requirement, but some respondents seemed to believe that patents need not be reproducible by a PHOSITA without "undue experimentation."[139] An academic physicist who owns a spin-off company wrote that reproducibility "is not a requirement," and an academic chemist wrote: "Patents are designed not to enable other researchers to reproduce them. That would be self-defeating as far as I can tell. The goal is to protect an idea . . . . A key aspect of this is obfuscation." Another academic chemist expressed a similar sentiment: "Patents are written by attorneys, not scientists. Their purpose is to protect their legal rights, not to educate the reader or facilitate recreation of the experiment."

Finally, in addition to believing that the language of patents obfuscates the invention, some researchers worry that some patents are not reproducible because the patentee never possessed the invention in the first place. For example, an industrial chemist thought that "it was not clear if the inventors ever actually made the invention and saw that it worked as claimed," and an academic chemist had the same concern: "[T]here is insufficient reduction to practice. I think every inventor should be obliged to present a working invention before a patent is granted." An academic studying nanomechanics had witnessed the problems this has caused:

> [L]azy people sit in their office and say "we should do this" and the next minute they write a stupid invention disclosure and submit it, which an attorney (rightly) decides would help generate revenue in some form. . . . [T]he problem is such people rarely complete these projects . . . [and] someone who has the same idea will . . . find this patent application and assume it's been done before. I have seen personally many such great ideas not being pursued because of this. I firmly believe that any patent SHOULD have a demonstrability clause.

In conclusion, although many nanotechnology researchers have found useful technical details in patents (30% of all respondents, and 60% of those who have tried to find information in the patent literature), the majority of them believe that patents do not enable a skilled researcher to reproduce the invention.

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[139] *See supra* Section I.A.

### E. Do Researchers Worry About Willful Infringement?

The final issue probed by the survey was whether researchers avoid reading patents because of concerns about willful infringement, as suggested by a number of legal commentators.[140] The survey shows that among nanotechnology researchers, this is at most an extremely minor concern compared with other reasons for not reading patents. In this aspect, however, nanotechnology researchers are not representative of researchers in general, as many of them probably do not have products on the market—it would be interesting to repeat this survey among more industrial researchers.

Nanotech researchers who indicated that they have *not* read a patent were given the option "I am worried about the negative legal effects of looking at patents" as one of the possible reasons to check, and only two out of seventy-six respondents (three percent) checked this option. Based on their follow-up remarks, it seems unlikely that they were thinking of willful infringement—they seem more concerned about the negative effects of patents on science. The first was a mechanical engineer working in a government lab who said he would only read a patent if he "was chained to a chair and water dripped on [his] head." He called patents "stifling to research" and wrote a long diatribe against patenting by universities. The second was an academic in electrical engineering who criticized the granting of "theoretical patents" because "it is incredibly short-sighted to think that what you expect to happen in the lab is actually going to happen." Researchers were not specifically asked about whether they believe that there is an experimental use exemption to patent infringement, but one respondent commented that he is "only glad that patents cannot be applied to restrict the freedom of academic scientific research."[141]

Researchers who *have* read patents were specifically asked if they "worry that reading patents could have negative legal effects." Only six out of 134 (four percent) said yes, and only three of these expressed concern about liability for infringement (for example, one researcher said he was concerned "only since you asked this

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[140] *See supra* note 67 and accompanying text.

[141] *But see* Zhen Lei, Rakhi Juneja & Brian D. Wright, *Patents Versus Patenting: Implications of Intellectual Property Protection for Biological Research*, 27 NATURE BIOTECHNOLOGY 36, 37 (2009) (finding that over eighty percent of eighty-five U.S. agricultural biology faculty disagreed with a statement that academic researchers have a research exemption).

question"[142]). An industry chemist said that under his company's policy, "the only time we actually read a patent is if it has been given to us by an attorney to answer a specific question." An industry physicist was concerned about infringement, though misinformed about patent liability for independent creation, writing that "if you reinvent . . . without knowledge of the patent then you may not be held accountable for infringement." The most detailed understanding was demonstrated by an academic physicist: "[I]f I can reinvent something on my own, it demonstrates that it is obvious to one skilled in the art, and I could avoid triple damages for knowing infringement." These three respondents (under two percent of the entire sample) are the only ones who might be characterized as avoiding patents because of infringement concerns (willful or otherwise).

The majority of patent readers who said they did not worry about the negative legal effects of reading patents expressed confusion about the question. One academic physicist's response was representative: "Surely I have the right to read patents once they've been issued. It is difficult for me to see how that could have a negative legal effect upon anyone." Only one respondent who said "no" demonstrated any knowledge about willful infringement, and he was the business-degree holder in industry who was excluded from the statistics presented here because he is not a scientist.[143] He wrote: "I do know about the 'dance' of intentionally avoiding patents so as to genuinely not have prior knowledge, but I find in nearly all cases that NOT reading patents would have greater negative [legal] effects than reading them."

## III. Nanotechnology Patent Case Studies

The survey results described in the previous Part show that many nanotechnology researchers do find patents to be a useful source of technical information—though many also have concerns that patents are not reproducible and think that the value of patent disclosures could be improved.

In this Part, specific nanotechnology patents (and pending patent applications) are examined in more detail by me and by others with experience in nanotech research. The patents chosen were the

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[142] The small number of positive responses to this question is even more striking when one considers the potentially leading nature of my survey question.

[143] *See supra* note 115 and accompanying text.

most relevant to these specific areas of expertise, and I have no reason to believe they are more or less useful than an average nanotech patent. These discussions do not purport to be comprehensive surveys of the patent coverage of the topics discussed or opinions about patent validity; rather, the aim is to briefly give some concrete examples of the kinds of technical information that researchers find in patents that is not redundant with scientific papers, as well as ways in which patents could be improved.

### A. Carbon Nanotube Resonators

Carbon nanotubes are tiny rolled-up sheets of graphene (like in a pencil) with a diameter of about a nanometer.[144] The many potential applications of carbon nanotubes have led to a crowded patent landscape.[145] One of these applications is the use of nanotubes in nanoelectromechanical systems (NEMS), where researchers essentially use an electrical current to shake the nanotube, much as you can shake a jump rope with one person at each end, with the potential for measuring tiny masses, processing radio signals, and exploring quantum phenomena.[146] The first self-detecting nanotube resonator was created by Vera Sazonova and colleagues and reported in the journal *Nature*.[147] Sazonova agreed to review four nanotube resonator patents for this Article; I selected these patents based on their relevance to her research and explained the basic requirements of patentability.

Overall, she was surprised to learn that it is possible to patent "something that CAN be envisioned, given all the technologies of the day (kind of a Gedankenexperiment)," rather than "a particular invention that has been implemented and shown to work." Her comments on the usefulness of the more "theoretical" patents illustrate the problems with the constructive reduction to practice doctrine, as discussed in Section I.A. She was also "surprised about the scope of the claims . . . since depending [on] how you read them they cover almost any NEMS," which seemed "absurd." Still, she was

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[144] *See* Lisa Larrimore, *Ask a Scientist! Formation of Carbon Nanotubes Requires Heat, Carbon, Catalyst*, CORNELL CENTER FOR MATERIALS RES. (July 1, 2004), http://www.ccmr.cornell.edu/education/ask/?quid=801 (providing an explanation for non-specialists of what carbon nanotubes are and how they are formed).

[145] *See* John Miller & Drew Harris, *The Carbon Nanotube Patent Landscape*, 3 NANOTECHNOLOGY L. & BUS. 427 (2006).

[146] *See* Vera Sazonova et al., *A Tunable Carbon Nanotube Electromechanical Oscillator*, 431 NATURE 284, 284 (2004).

[147] *See id.*

pleasantly "surprised [by] how easy it was to read the patents," and she learned some things by reading them.

The first patent Sazonova examined, for a tunable nanotube resonator, is assigned to the California Institute of Technology and has a priority date of 2001 (three years before her *Nature* paper).[148] She thought it was the least informative of the four patents she read. When I asked whether it would have been useful to read this patent in 2001, when she was at the early stages of her research project, she wrote:

> I think it would have been useful to read it, at least to know that we were not alone [in] thinking of building a NT resonator that way. Would it have been useful technically? Not really, he's not describing anything new, all the parts existed in [the] literature already. And he is not giving any solutions to any problems we have encountered on the way.

The fabricated devices proposed in the patent "were very similar" to her own, but she felt that the inventors did not anticipate many problems with measuring the resonators.[149] But for a nanotube expert who wanted to build a nanotube resonator, she thought this patent "is a good place to start, just as good as reading some papers on NEMS."

The second patent Sazonova read, claiming a NEMS transistor very similar to her own device, was filed in 2005 by an industrial researcher.[150] She wrote, "I agree it is surprising that [the inventor] doesn't [c]ite our paper since his second embodiment, the resonating transistor channel, is identical to ours minus the readout scheme." Like the first patent, she found it "purely speculative," with

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[148] *See* Pattern-Aligned Carbon Nanotube Growth & Tunable Resonator Apparatus, U.S. Patent No. 6,803,840 (filed Apr. 1, 2002) (claiming priority to a provisional applications filed on Mar. 30, 2001).

[149] In particular, she said that the patent proposes "to use charge injection to modulate the length," but "that effect will be much smaller than the electrostatic attraction that would be present anyway, something that [the patentees] didn't anticipate." The patent also does not consider how to prevent "capacitive coupling between electrodes 18 and 28," how to separate "tension induced with the charge injection" from "tension due to the attractive force between the resonating member and the electrode 28," how "the RF signal [will] be read out of a high-impedance resonating member[] without [an] integrated amplifier," or "[w]hat kind of contact resistances are produced with this fabrication method . . . and how will they affect the charge injection."

[150] *See* Carbon Nanotube Resonator Transistor & Method of Making Same, U.S. Patent No. 7,579,618 (filed Mar. 2, 2005).

"absolutely no details on how to implement the invention."[151] But she did think certain technical aspects were useful, and she said that a particular calculation was at least "one of the firsts."[152]

The third and fourth patent documents Sazonova read were patent applications that have not yet been granted; both came from the lab of Alex Zettl, a physics professor at U.C. Berkeley.[153] The third, which has a priority date in 2005, describes a telescoping nanotube resonator, in which one nanotube slides inside another "[l]ike a trombone player shifting notes."[154] Sazonova liked that "[t]his invention has been implemented and the result is present," and she thought the analysis was "[v]ery interesting." This patent application was thus more useful than the first two patents, but it is also duplicative of the technical literature: most of it is directly copied from two of Zettl's papers,[155] with the fabrication details for both the patent and those two papers coming from three earlier papers.[156]

The fourth patent document was a patent application for a high-frequency nanotube resonator, which has a priority date in 2006.[157] Although this application also stems from a Zettl group

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[151] In particular, it does not specify the "choice of materials compatible with [nanotube] growth," the "necessary read-out and actuation electronics," or "how . . . the electrical impedance problem [is] resolved." Sazonova also did not think it was clear why there is "a time-varying electric field in a [nanotube] due to mechanical vibrations": "If it is capacitively induced, then why will the signal be much larger than the parasitic signal?"

[152] For specialists, Sazonova liked the "calculation of the charge injection vs. electrostatic force" and the fact that the patent acknowledged "the importance of read-out electronics due to high motional impedance." She also "found the discussion about the dynamic resistance of the [nanotube] resonator" very useful, saying that "this calculation is one of the firsts."

[153] *See Zettl Research Group*, DEP'T PHYSICS U.C. BERKELEY, http://www.physics.berkeley.edu/research/zettl/ (last visited Jan. 20, 2011).

[154] Tunable Multiwalled Nanotube Resonator, U.S. Patent Application No. 11/467,422 ¶ 42 (filed Aug. 25, 2006) (claiming priority to a provisional application filed on Aug. 25, 2005).

[155] *See* K. Jensen et al., *Tunable Nanoresonator*, 786 AIP CONF. PROC. 607 (2005); K. Jensen et al., *Tunable Nanoresonators Constructed from Telescoping Nanotubes*, 96 PHYSICAL REV. LETTERS 215503-1 (2006).

[156] *See* John Cumings et al., *Peeling and Sharpening Multiwall Nanotubes*, 406 NATURE 586 (2000); John Cumings & A. Zettl, *Localization and Nonlinear Resistance in Telescopically Extended Nanotubes*, 93 PHYSICAL REV. LETTERS 086801-1 (2004); John Cumings & A. Zettl, *Low-Friction Nanoscale Linear Bearing Realized from Multiwall Carbon Nanotubes*, 289 SCIENCE 602 (2000).

[157] High Frequency Nanotube Oscillator, U.S. Patent Application No. 12/446,231 (filed Oct. 19, 2007). Note that this patent application claims priority to

paper,[158] Sazonova believed that it provided information that was nonduplicative of the paper:

> [T]his patent is not a direct copy of the paper, rather it's a[n] elongated version of the paper. . . . The patent gives alternative routes [of fabrication] and gives a list of other materials that could be used in a similar recipe. . . . The actuation/detection method is elaborated on . . . . And there is an additional discussion on the origins of dissipation.

Not only did this patent application contain details that were not in the technical literature, but Sazonova also believed that it "is the only patent that provides enough information for those skilled in [the] art to reproduce their invention" out of the four patents or patent applications that she read.

### B. Carbon Nanotube Sensors

In addition to having amazing mechanical properties for use as resonators, carbon nanotubes also have remarkable electronic properties: some nanotubes are metallic (so that they conduct electricity as tiny wires), while others are semiconducting (so that the current through them is sensitive to their external environment).[159] Coupled with their small size (comparable to a DNA molecule) and ability to operate in air or under water, this makes nanotubes promising sensors for detecting a variety of chemical and biological molecules.[160] For my Physics Ph.D., I fabricated many carbon nanotube devices for chemical and biological sensing, and I conducted a thorough literature review of other work in the field.[161] This section describes my own thoughts on the technical content of some carbon nanotube sensor patents.

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a provisional application filed on October 19, 2006, it was not published until August 26, 2010. *See id.*

[158] *See* H.B. Peng et al., *Ultrahigh Frequency Nanotube Resonators*, 97 PHYSICAL REV. LETTERS 087203-1 (2006).

[159] *See* Paul L. McEuen, *Single-Wall Carbon Nanotubes*, PHYSICS WORLD, June 2000, at 31 (summarizing the electronic properties of carbon nanotubes).

[160] For an overview of nanotube sensors for non-specialists, see *Probing Biological Systems with Carbon Nanotubes*, NANOBIOTECHNOLOGY NEWS, March 2007, at 1, *available at* http://www.nbtc.cornell.edu/pdf%20files/newsletter%20March07.pdf.

[161] *See* Lisa Larrimore Ouellette, Chemical and Biological Sensing with Carbon Nanotubes in Solution (Jan. 2008) (unpublished Ph.D. dissertation, Cornell University), *available at* http://www.lassp.cornell.edu/lassp_data/mceuen/homepage/Publications/Thesis_Larrimore.pdf.

The first nanotube sensing results were published by Jing Kong and colleagues in Hongjie Dai's Stanford laboratory; they discovered that the current through a nanotube transistor changes in response to exposure to gaseous nitrogen dioxide or ammonia.[162] Kong and Dai also filed a provisional patent application on their nanotube sensor invention in December 1999, which has grown into a family of at least five patents and patent applications—all of which are unhelpfully titled "Carbon Nanotube Devices."[163] For the most part, all the technical details in the paper are also in the patents, and the patents contain some information that is only available in references in the paper. For example, the paper says that nanotubes were grown "from patterned catalyst islands" and cites to earlier works for the details,[164] while the initial patent provides the details of the catalyst recipe and specifies that for this experiment the catalyst islands "are typically 5 microns in size, spaced at a distance of 10 microns apart."[165] The patent also offers some alternative suggestions to the fabrication steps in the paper, such as making the electrodes out of titanium and gold instead of nickel and gold.[166]

As might be expected, the patent literature becomes more uniquely helpful when describing industry research, rather than the work of academics. Many of the early nanotube sensing experiments were performed by the company Nanomix, Inc.[167] For some results, Nanomix published in the scientific literature in addition to seeking a patent, including for sensing DNA hybridization,[168] protein binding,[169] and starch degradation.[170] These patents are not simply

[162] *See* Jing Kong et al., *Nanotube Molecular Wires as Chemical Sensors*, 287 SCIENCE 622 (2000).

[163] *See* The initial nanotube sensor patent was U.S. Patent No. 6,528,020 (filed May 19, 2000). This '020 patent had at least four "child" patents. *See* U.S. Patent Application No. 10/299,610 (filed Nov. 18, 2002) (divisional of the '020 patent); U.S. Patent No. 7,166,325 (filed Nov. 18, 2002) (continuation-in-part of the '020 patent); U.S. Patent Application No. 10/175,026 (filed June 18, 2002) (divisional/continuation of the '020 patent); U.S. Patent No. 7,416,699 (filed June 18, 2002) (divisional of the '020 patent). All of these patents have the same figures.

[164] Kong et al., *supra* note 162, at 623.

[165] U.S. Patent No. 6,528,020 col.3 l.54-55 (filed May 19, 2000).

[166] *See id.* col.4 l.32.

[167] *See* Ouellette, *supra* note 161, at 57-61.

[168] *See* Nanotube Sensor Devices for DNA Detection, U.S. Patent Application No. 11/212,026 (filed Aug. 24, 2005); Alexander Star et al., *Label-Free Detection of DNA Hybridization Using Carbon Nanotube Network Field-Effect Transistors*, 103 PNAS 921 (2006).

[169] *See* Nanotube-Based Electronic Detection of Biological Molecules, U.S. Patent Application No. 10/704,066 (filed Nov. 7, 2003); Alexander Star et al.,

duplicative of the scientific papers; for example, Ethan Minot, a physics professor with experience in nanotube biosensors,[171] noted that the DNA hybridization patent contains three detailed examples that are not given in the paper, which "give more thorough step-by-step instructions."[172] Even more significantly, the Nanomix researchers filed patents on a number of inventions that are not disclosed in any of their scientific papers,[173] including for sensing carbon dioxide,[174] hydrogen,[175] and other gases.[176] Each of these patents displays data from their sensors in addition to describing their experimental setup.

In my search for nanotube sensing patents, I also came across two other industry patents that contain data from working inventions: one from Molecular Nanosystems, Inc.,[177] and another from Nano-Proprietary, Inc.[178] Although I scoured the scientific literature for nanotube sensing results to review in my Ph.D. dissertation, I never saw these results, or those from Nanomix, before turning now to the patent literature—even though all of them were published before I completed my dissertation. In other words, the patent contains useful information that is nonduplicative of the scientific literature, even if it does not contain all the details that a researcher might hope.

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*Electronic Detection of Specific Protein Binding Using Nanotube FET Devices*, 3 NANO LETTERS 459 (2003).

170 *See* System and Method for Electronic Sensing of Biomolecules, U.S. Patent Application No. 11/259,414 (filed Oct. 25, 2005); Alexander Star et al., *Electronic Detection of the Enzymatic Degradation of Starch*, 6 ORGANIC LETTERS 2089 (2004).

171 *See Minot Research Group Publications*, DEP'T PHYSICS OR. ST. U., http://www.physics.orst.edu/~minote/pubs.php (last visited Jan. 22, 2011).

172 Although he was pleased with the technical content of the patent, he was skeptical of the broad claims: "[F]rom their limited set of three examples using [carbon nanotubes], the patent claims many things, [such as] using any 'nanostructure' to make such a sensor (claim 29). Also, they claim every functionalization chemistry they can think of (claims 36-50). Developing these functionalization schemes is a major challenge—they have only demonstrated a small subset, yet claim many."

173 *See Publications*, NANOMIX, http://nano.com/news/archives/publications.html (last visited Jan. 22, 2011).

174 *See* U.S. Patent No. 7,547,931 (filed Dec. 20, 2004).

175 *See* U.S. Patent Application No. 11/354,561 (filed Feb. 14, 2006).

176 *See* U.S. Patent Application No. 11/400,038 (filed Apr. 6, 2006).

177 U.S. Patent No. 7,052,588 (filed Nov. 26, 2003).

178 U.S. Patent No. 7,399,400 (filed Sept. 29, 2004).

# IV. Implications for Patent Policy

The results from Parts II and III suggest that patents can be useful as sources of technical information, but also that many patents may not be enabled and that disclosure could be improved. This Part highlights some recommendations for patent policy in three key areas.

Section IV.A explains how existing disclosure requirements should be more stringently enforced. I argue that the benefits of more robust disclosure outweigh any costs to innovation incentives. I then suggest that enforcement could be improved through increased peer review of patents—both public peer review through the Peer To Patent program and traditional peer review by a few designated experts—and by imposing an obligation on inventors to respond to good faith enablement questions from those skilled in the art.

Section IV.B describes legal barriers to disclosure. Although Part II demonstrated that concerns about infringement liability do not dissuade many researchers from reading patents, I argue that an expanded experimental use exemption and a scaled back willful infringement doctrine would help make patent laws reflect traditional scientific norms and expectations. I also propose that the time to patent publication be shortened from its current eighteen months so that researchers have access to information before it becomes out of date.

Finally, Section IV.C explores ways for third parties, including the research community, to improve access to the patent literature. This Section builds on existing work about peer production of information.

## A. Strengthen Enforcement of Disclosure Requirements

The PTO and the courts should greatly strengthen enforcement of existing disclosure requirements. The previous evidence presented in Section I.C and the new results presented in Parts II and III demonstrate that many researchers (in my survey, 30% of all respondents, and 60% of those who have tried to find information in the patent literature) are finding useful technical information in patents that is not available in the scientific literature. But most researchers feel that patents are not reproducible by an expert in the field—one even feels that patents are "designed not to enable"[179]—which raises serious questions about whether the enablement requirement is typically satisfied.

Many suggestions have been made for improving the content of patent disclosures, including separating a patent into separate legal and technical layers,[180] requiring source code for software patents,[181] requiring biotechnology patents to conform to database specifications (like for the Protein Data Bank),[182] using rebuttable presumptions in litigation,[183] and requiring actual reduction to practice and the description of working examples.[184] These suggestions are generally sound, and the survey responses suggest other improvements, such as changing the "deplorable" practice where "figures are given early on and the description is usually 10 pages away."[185] But I focus in this Section on two other proposals: peer review of patents (both public peer review and traditional peer review)[186] and the novel suggestion of imposing an obligation that patentees respond to good-faith questions about reproducibility.

Before addressing these specifics of how stronger enforcement could be accomplished, however, it is important to consider the

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[179] *See supra* Section II.D.

[180] *See* Fromer, *supra* note 7, at 569. Fromer offers useful suggestions for constructing the technical layer, though her proposal that it should include dynamic three-dimensional models is probably ahead of its time because there is not currently a standard three-dimensional format and scientists are not used to obtaining information this way. *See id.* at 575.

[181] *See* Michael J. Walsh, Comment, *The Disclosure Requirements of 35 U.S.C. 112 and Software-Related Patent Applications: Debugging the System*, 18 CONN. L. REV. 855, 871 & n.87 (1986) (providing the first suggestion in the legal literature that the PTO require source code for disclosure of software patents).

[182] *See* Helen M. Berman & Rochelle C. Dreyfuss, *Reflections on the Science and Law of Structural Biology, Genomics, and Drug Development*, 53 UCLA L. REV. 871, 898-99 (2006).

[183] Timothy Holbrook argues that "the Federal Circuit has removed considerations of the PHOSITA from assessing the sufficiency of patent disclosures," creating "incentives to reduce the technical aspect of the document in favor of creating a more legalistic text," and that a "presumption-based approach would require courts to readily consider the technological evidence." Timothy R. Holbrook, *Patents, Presumptions, and Public Notice*, 86 IND. L.J. (forthcoming 2011) (manuscript at 13, 45), *available at* http://ssrn.com/abstract=1650819. While I support this general project, I do not think the problem is that "the Federal Circuit has now incentivized vast overdisclosure." *Id.* at 27.

[184] *See* Cotropia, *supra* note 37; Seymore, *supra* note 7, at 641-46.

[185] *See supra* Section II.D.

[186] Jeanne Fromer also discusses the possibility of patent peer review. *See* Fromer, *supra* note 7, at 591-92.

potential costs of this proposal. Subsection IV.A.1 examines the costs and benefits of stronger disclosure, and then Subsection IV.A.2 presents my proposals for improved disclosure.

#### *1. Is Better Disclosure Worth the Cost?*

As discussed previously, I agree with critics of disclosure theory that disclosure is not a compelling justification for the patent system, and I think focusing on this question leads to misleading conclusions about disclosure.[187] Rather, I think the relevant question is whether the marginal benefits of stronger disclosure outweigh the resulting marginal costs—and I believe the answer is yes. These costs and benefits are difficult to quantify. The only commentator to address this tradeoff is Alan Devlin, who reached the opposite conclusion: "[O]ne can safely conclude that society is better off with a patent system that incentivizes invention and commercialization without requiring disclosure than with a system that dilutes ex ante incentives and reduces the incidence of invention by demanding as much disclosure as possible."[188] But his argument depends on his premise that the disclosure function of patents is not currently working,[189] and he did not provide any explanation of the costs or benefits.[190]

My empirical results illustrate some underappreciated benefits of patent disclosures. Patents do disclose information that other researchers find useful, and this Part will address ways to make the information even more valuable. The useful information in patents is not always the key information about the invention itself—patents can have many audiences and many unintended uses. Further improving the technical content of disclosures would also increase scientists' trust in, and respect for, the patent system. The benefits of strong disclosure are thus substantial.

Stronger disclosure might, however, cause three kinds of costs. First, disclosure takes time, and asking each inventor (or her patent agent) to rewrite details that are already clearly described in the literature would clearly be inefficient. But the costs of using plainer language or providing a few additional key details about the heart of the invention are unlikely to be significant.

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[187] *See supra* Section I.B.

[188] Devlin, *supra* note 5, at 406.

[189] *See id.* at 403-04 (claiming that disclosure is "ineffective" because specifications are "inadequate" and "inventors simply ignore patents").

[190] *See id.* at 419-21 (concluding that there is a tradeoff between disclosure and innovation, but providing no guidance for how to measure the costs or benefits).

Second, if disclosure were strengthened to exclude non-enabling constructive reductions to practice from patentability—such as the first two nanotube resonator patents examined by Vera Sazonova[191]—then these incomplete disclosures would not be in the patent literature at all, even though they may still provide some useful information. But if these patents are truly speculative patents that would require undue experimentation to implement, then it is inefficient to grant these patents and allow these patentees to tax future inventors.

Third, and most significantly, stronger disclosure requirements may weaken innovation incentives. Better disclosure may make it easier for competitors to build on and appropriate inventions, so more inventors might choose trade secret protection over patents or choose not to innovate at all. Similarly, if the disclosed information is valuable enough that someone would have independently paid for it (and, importantly, if the transaction costs are not too high), this will also decrease the patent rents.

These innovation costs, however, are likely to be minimal. Here, the third critique of disclosure theory as a *justification* for the patent system—that only "self-disclosing" inventions will be patented[192]—cuts against the argument that stronger disclosure would hurt innovation. The inventions most likely to be patented are those that are relatively easy to reverse engineer (compared with their original research cost),[193] and inventors have no other option to protect these inventions.[194] The costs are more difficult to measure for inventions that are easier to protect as trade secrets, but as Alan Devlin acknowledges, creators of these inventions still have many reasons to turn to the patent system, including risk-aversion.[195]

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[191] *See supra* Section III.A.

[192] *See supra* notes 76-78 and accompanying text.

[193] *See* Burk & Lemley, *supra* note 46, at 1585 (arguing that the "ratio of R&D cost to imitation cost" is a good measure for the importance of patent protection).

[194] Devlin draws the confusing conclusion that "given the patent system's ultimate goal of incentivizing the creation and commercialization of valuable technology, scant normative justification exists for allowing inventors of 'self-realizing' discoveries to appeal to patent law for protection." *Id.* at 425. If patents were only justified by disclosure, there would be little reason to allow patents on "self-disclosing" inventions (because they would be disclosed anyway), but under innovation theory the justification is *strongest* for allowing patents on these inventions because inventors cannot protect these inventions with trade secrets, so absent patent protection there would be no incentive for their creation.

[195] *See id.* at 427-31.

More importantly, empirical evidence has questioned whether patents actually incentivize much innovation outside the pharmaceutical industry.[196] And stronger enforcement of disclosure requirements would be least likely to affect innovation incentives in the drug industry both because pharmaceutical inventions are relatively easy to imitate (so companies cannot turn to trade secret protection),[197] and because pharmaceutical patents are among the best-described patents.[198] Finally, even if stronger disclosure does weaken the strength of patent protection, this may actually be a benefit, given concerns about patent protection currently being *too* strong.[199]

Lingering concerns about the costs to innovation could be mitigated by a system in which inventors can opt in to more stringent enforcement of the disclosure requirements. This would be similar to proposals for a more rigorous "gold-plated" review process that would allow patents to emerge with a higher presumption of validity.[200] Since inventors could still choose the current review system, it seems unlikely that the availability of heightened scrutiny would reduce innovation incentives or cause inventors to choose trade secret

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[196] *See supra* note 52 and accompanying text. For a summary of why patents work comparatively well in the pharmaceutical industry, see Lisa Larrimore Ouellette, Note, *How Many Patents Does It Take To Make a Drug? Follow-On Pharmaceutical Patents and University Licensing*, 17 MICH. TELECOMM. TECH. L. REV. 299, 302-04 (2010).

[197] *See* Ouellette, *supra* note 196, at 302 (comparing imitation to research costs in the pharmaceutical industry).

[198] *See* Devlin, *supra* note 5, at 411 & n.53 (noting that "the pharmaceutical sector [is] the prime example" of an industry where patents usefully disclose information). This calculus might change, however, for biopharmaceuticals. *See* Gregory N. Mandel, *The Generic Biologics Debate: Industry's Unintended Admissions that Biotech Patents Fail Enablement*, 11 VA. J.L. & TECH. 8 (2006).

[199] *See, e.g.*, BESSEN & MEURER, *supra* note 53; MICHELE BOLDRIN & DAVID K. LEVINE, AGAINST INTELLECTUAL MONOPOLY (2008); ADAM B. JAFFE & JOSH LERNER, INNOVATION AND ITS DISCONTENTS: HOW OUR BROKEN PATENT SYSTEM IS ENDANGERING INNOVATION AND PROGRESS, AND WHAT TO DO ABOUT IT (2004).

[200] The idea of gold-plated patents was first suggested in a short article for a non-legal audience. *See* Mark Lemley, Doug Lichtman & Bhaven Sampat, *What To Do About Bad Patents?*, REGULATION, Winter 2005-2006, at 10. Lemley and Lichtman then developed the idea in more detail. *See* Doug Lichtman & Mark Lemley, *Rethinking Patent Law's Presumption of Validity*, 60 STAN. L. REV. 45 (2007). Jeanne Fromer has also suggested that "the government might offer a sliding scale of patent rights calibrated in part to the quality of disclosure," Fromer, *supra* note 7, at 598, and Kristen Osenga has discussed how different patent "highways" might work, Kristen Osenga, *Entrance Ramps, Tolls, and Express Lanes—Proposals for Decreasing Traffic Congestion in the Patent Office*, 33 FLA. ST. U. L. REV. 119 (2005).

protection. The idea of gold-plated review has been criticized for its likely added expense,[201] but some proposals (like free peer review) would add little cost for the PTO, and the gains in improved patent quality would probably outweigh these costs.[202] These added costs would also be lower under an opt-in gold-plating system than under a system where the disclosure requirements are strictly enforced for all patents.

### *2. How To Strengthen Disclosure*

The PTO is already experimenting with an opt-in system of heightened scrutiny through the Peer To Patent program, now in its second pilot, which lists patents online for the public to submit prior art that might be relevant to novelty or non-obviousness.[203] Although this program does not officially provide a higher presumption of validity, patent blogger Dennis Crouch has suggested that it is analogous to gold plating: "Peer-to-Patent offers a potential mechanism to bolster the credibility of [applicants'] patent rights. I can imagine the patentee's top litigator explaining to the jury that—in addition to the ordinary rigorous examination process—the applicant volunteered its patent for the gold-standard of academic review—public peer-review."[204] Peer To Patent is focused only on finding prior art that has bearing on novelty or non-obviousness, not on evaluating whether the invention is adequately disclosed, but there is no reason that it could not be expanded to allow questions about enablement. In fact, peer review would probably be *more* useful for evaluating

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[201] *See* Donald Zuhn, *Presidental "Debate" on U.S. Patent Policy*, PAT. DOCS (Oct. 14, 2008), http://patentdocs.typepad.com/patent_docs/2008/10/presidential-debate-on-us-patent-policy.html (reporting that during the 2008 presidential campaign, Barack Obama's plan to implement the gold-plated patent scheme was criticized by the McCain campaign for its expense).

[202] *See* Lichtman & Lemley, *supra* note 200, at 65-66 (responding to this objection).

[203] *See* PEER TO PAT., http://www.peertopatent.org/ (last visited Dec. 15, 2010). The second pilot, which lasts until September 2011, was announced after the success of the first 2007 to 2009 pilot. *See* Press Release, U.S. Patent & Trademark Office, USPTO Launches Second Peer To Patent Pilot in Collaboration with New York Law School (Oct. 19, 2010), *available at* http://www.uspto.gov/news/pr/2010/10_50.jsp. For an overview of the Peer To Patent concept, see Beth Simone Noveck, *"Peer to Patent": Collective Intelligence, Open Review, and Patent Reform*, 20 HARV. J.L. & TECH. 123 (2006). For a discussion in the context of disclosure, see Fromer, *supra* note 7, at 592 n.245.

[204] Dennis Crouch, *Peer-to-Patent Begins Expanded Pilot*, PATENTLYO (Oct. 19, 2010, 8:31 AM), http://www.patentlyo.com/patent/2010/10/peer-to-patent-begins-expanded-pilot.html.

disclosure than novelty: patent examiners are generally not PHOSITAs, and it is easier for non-experts to locate relevant prior art than to recognize enablement problems.[205]

The PTO could also send patents out for traditional peer review, rather than (or in addition to) opening them up for public peer review on the Peer To Patent website. I have suggested that getting a patent should be more like getting an article in a top scientific journal, and journals all send their articles out for peer review.[206] As described in Section II.B, a number of survey respondents were skeptical of the patent literature because of the lack of peer review. Although patents are reviewed by scientifically trained patent examiners, they (like journal editors) have a limited degree of specialization. They could send some subset of patents (either those that they have questions about, or those that are part of an opt-in system) to experts in the field for opinions on disclosures. To help cover the costs, the PTO could charge an additional fee for peer review, which could be waived if the patentee is able to have the patented idea accepted by a peer-reviewed journal within a year of submitting the patent application.[207]

Because scientists are accustomed to peer reviewing articles for free, many would probably willingly respond if the PTO asked for their opinion about whether a patent is enabled.[208] For some inventions, this could be judged based on the patent document alone;

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[205] This problem could also be addressed by having "the burden shift to the applicant to establish patentability" when the application "lacks working examples or is supported by prophetic examples." Sean Seymore, *supra* note 19, at 156.

[206] Beth Noveck argues that traditional peer review is inappropriate for patents by discussing peer review in other government agencies, *see* Noveck, *supra* note 203, at 138-43, but the practice of peer review for technical papers seems like the more relevant analogy.

[207] In the United States, patentees have a one-year grace period between publishing their idea and submitting a patent application. *See* 35 U.S.C. § 102(b) (2006). Most other countries, however, require absolute novelty, such that any publication before the application is submitted would preclude patentability. *See* 2 R. CARL MOY, MOY'S WALKER ON PATENTS § 8:208 (4th ed. 2010). Many patentees would thus not want to wait until after an idea is published to submit their application; for example, one survey respondent wrote, "In my group, we tend to write a paper for a scientific journal and a patent simultaneously, and when we receive notice that the application has been received by the USPTO, we submit the paper to a journal." But patentees would still have time to alert the PTO if they have their idea accepted by a peer-reviewed journal, as "it is generally more than a year, and sometimes more than two, before the examiner even picks the application up off the pile." DAN L. BURK & MARK A. LEMLEY, THE PATENT CRISIS AND HOW THE COURTS CAN SOLVE IT 23 (2010).

[208] This may not be the case in non-technological fields, such as for business method patents.

in other cases, the PTO might pay reviewers to try to reproduce the invention based on the disclosure, along with any source code or materials provided by the patentee.[209] Like the editors at *Science* and *Nature*, patent agents would not be bound by the results of peer review,[210] and reviewers should be required to disclose conflicts of interest, which would mitigate problems with bad faith reviews by competitors. But the reviews should still be highly informative—if experts in the field give reasons why they could not reproduce an invention without undue experimentation, then the patent is probably not adequately disclosed.

Implementing peer review for every patent might be administratively difficult for the PTO, but it would not be limited by the number of scientists who are willing to peer review articles. For the past ten years, the PTO has typically issued between 150,000 and 200,000 utility patents per year.[211] The ISI Science Citation Index, which covers 6,650 major peer-reviewed scientific journals, averages nearly one million new articles per year.[212] In 2009, the PTO issued 2675 patents with "nano" in one of their claims,[213] while the Science Citation Index contains 66,913 articles from 2009 with "nano" in the topic field.[214]

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[209] Note that it is not currently required that every disclosed suggestion work. *See* Atlas Powder Co. v. E.I. du Pont De Nemours & Co., 750 F.2d 1569 (Fed. Cir. 1984) (stating that "[e]ven if some of the claimed combinations were inoperative, the claims were not necessarily invalid," and that "[u]se of prophetic examples . . . does not automatically make a patent non-enabling").

[210] *See Peer Review at* Science *Publications*, SCIENCE, http://www.sciencemag.org/site/feature/contribinfo/review.xhtml (last visited Dec. 23, 2010); *Peer-Review Policy*, NATURE, http://www.nature.com/authors/editorial_policies/peer_review.html (last visited Dec. 23, 2010).

[211] *See* U.S. PATENT & TRADEMARK OFFICE, ALL TECHNOLOGIES REPORT: JANUARY 1, 1963—DECEMBER 31, 2009, at 4 (2010), *available at* http://www.uspto.gov/web/offices/ac/ido/oeip/taf/all_tech.pdf.

[212] *See Web of Science Databases*, ISI WEB OF KNOWLEDGE, http://images.isiknowledge.com/WOK46/help/WOS/h_database.html (last modified Feb. 17, 2009) (noting that the Science Citation Index averages 19,000 new records per week).

[213] *See USPTO Patent Full-Text and Image Database*, *supra* note 126 (search for "ISD/$/$/2009 and ACLM/nano$").

[214] *See Web of Science Advanced Search*, ISI WEB OF KNOWLEDGE, http://apps.isiknowledge.com/WOS_AdvancedSearch_input.do?product=WOS&SID=2DLF%40BLfiK1ChGfPApd&search_mode=AdvancedSearch (select timespan from 2009 to 2009, check the box only for "Science Citation Index Expanded," and search for "ts=nano*") (last visited Dec. 23, 2010).

I also propose that disclosure could be enforced in a novel way by giving patentees an obligation to respond if a PHOSITA asks a good-faith question about reproducibility. In the scientific community, if a researcher has trouble replicating the result from a technical paper, she will often contact the paper's authors to explain her difficulty and ask for guidance, and the authors are generally willing to assist with reasonable requests. (Such requests do not necessarily mean that the papers were not "enabled"—for example, authors may have suggestions about troubleshooting or common mistakes.) As part of an effort to bring the patent system more in line with scientific norms, I argue below that the inventors listed on patents should be expected to respond to similar questions.

To implement this, a court could simply decide that evidence that an inventor did not respond to a question about enablement raises a presumption that the patent is not enabled. This presumption should be available to anyone who wishes to challenge the patent, whether in defense to an infringement suit or in another proceeding. The inventor could rebut this presumption by demonstrating that the question was vexatious or that the questioner was not a PHOSITA.[215] This idea would be further facilitated if the PTO accepted unanswered questions for a patent's file, or if a third party created a public website to collect such questions. Congress could also amend the Patent Act to allow the patentee to request compensation from the questioner at a statutory rate. The gain from this approach would have to be weighed against the potentially significant burden on the patentee—although this burden might incentivize patentees to write patents very clearly in the first place.

One logistical difficulty with this proposal is dealing with language barriers between researchers in different countries. Many international scientists communicate in English, with scientists in non-English-speaking countries writing most of their papers for English-language scientific journals, which facilitates international communication and collaboration. But a rule that discriminated against non-English-speaking inventors would violate the "national treatment" provision of TRIPS, which requires foreigners to receive "treatment no less favorable" than a country's own nationals.[216]

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[215] Although there is always the possibility of abuse, the United States has managed similar tradeoffs in favor of access to information, such as with the Freedom of Information Act (FOIA). *See* 5 U.S.C. § 552 (2006).

[216] *See* TRIPS, *supra* note 18, art. 3; *see also* Paris Convention for the Protection of Industrial Property, art. 2, Mar. 20, 1883, 21 U.S.T. 1583, 828 U.N.T.S. 305 (last revised July 14, 1967) (containing a similar national treatment provision).

Inventors who are unable to respond because they are difficult to locate raise a similar concern. The easiest way to deal with this problem would be to put the burden on the researcher seeking help to prove that the inventor actually received the question and that the question was in a language the inventor understands.

A different problem arises when a patent is assigned (or exclusively licensed) to a third party, as the new owner might not want the inventor to say anything that might affect the legal status of the patent. This could be addressed by limiting the period of the presumption, such as for one year after the patent is granted, or by again putting the burden on the researcher seeking help to contact the current owner of the patent.

A third problem with an obligation to respond to questions about reproducibility is that other inventors might be hesitant to reveal that they are trying to reproduce a patent invention because of concerns about being sued for willful infringement. As discussed in the following Section, a more robust experimental use doctrine and scaled back willful infringement rules would mitigate this problem. But even under current rules, some researchers do contact patentees about efforts to build on their inventions,[217] and the patent laws should help shape a norm that patentees should respond to these inquiries.

Both peer review and an obligation to respond to good faith questions will address the problem of obfuscating language as well as lack of technical information. If inventors know their applications will be reviewed by other scientists, not just by patent agents who are used to legalese, this will create an incentive to write for their peers. Similarly, obfuscating language will make it more likely that other scientists will need to ask questions about enablement, so applicants will have an incentive to write more clearly to avoid these questions in the first place, and their responses to questions will be available to help clarify remaining confusions.

In conclusion, whether the disclosure requirements of § 112 are enforced through an obligation to respond to questions about reproducibility, expanded peer review, or some of the suggestions from other commentators,[218] they should be enforced such that PHOSITAs believe that patented inventions are reproducible without undue experimentation. Courts may wish to adopt a more flexible view of what "new matter" is allowed in a disclosure without losing

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[217] *See* Jaffe et al., *supra* note 99.

[218] *See supra* notes 180-184 and accompanying text.

the priority date to encourage amendments,[219] but even if they do not, the threat of losing their priority dates will encourage patent applicants to have better-disclosed patents in the first place.

### B. Remove Legal Barriers to Using Patents as Technical Sources

In addition to more strongly enforcing existing disclosure requirements, the U.S. government should eliminate legal barriers to using patents as technical sources. Any of the three branches could take steps in this direction, as discussed below. In this section, I argue that they should (1) broaden the experimental use exemption; (2) limit the reach of willful infringement doctrine; and (3) reduce the time before patent publication.

The first two problems—the lack of a robust experimental use exception and the deterrent effect of willful infringement rules—are not actually deterring many innovators from reading patents. As described in Section II.E, less than two percent of the researchers I surveyed avoid reading patents because of concerns about adverse legal consequences (though the percentage is probably higher for more applied industrial researchers). And empirical evidence shows that the existence of patents rarely deters basic research.[220] I have previously argued that this evidence shows that "the need for an experimental use exemption is not as pressing as some have suggested,"[221] but it is an odd system in which inefficient laws are kept in place only because everyone ignores them. Patent laws help shape the norms and expectations of the scientific culture, and adjusting experimental use and willful infringement rules would help improve scientific trust in the patent system.

Experimental use exemptions—which prevent those who use patents only for basic research from being sued for infringement—exist in many other countries, including Canada, Japan, South Korea, Germany, the United Kingdom, and most other European countries.[222] The exemption was first suggested in the United States by a court in 1813, but it has rarely succeeded in practice.[223] In the

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[219] *See supra* note 16 and accompanying text.

[220] *See* Ouellette, *supra* note 21, ¶¶ 32-41 (summarizing survey evidence).

[221] *Id.* ¶ 39.

[222] *See* John F. Duffy, *Rethinking the Prospect Theory of Patents*, 71 U. CHI. L. REV. 439, 457 n.68 (2004).

[223] *See* Eisenberg, *supra* note 5, at 1023 & nn.21-22 (citing Whittemore v. Cutter, 29 F. Cas. 1120, 1121 (C.C.D. Mass. 1813)).

2002 case *Madey v. Duke*, the Federal Circuit made it clear that university research is not exempt from patent infringement.[224] This decision has been sharply criticized,[225] including in the context of nanotechnology.[226] I join academics who have argued for a broader experimental use exemption to help ensure that patent laws reflect traditional scientific norms.[227]

Willful infringement doctrine, which might subject parties who read patents to treble damages in infringement cases, was summarized in Section I.A.[228] As noted there, the Federal Circuit recently raised the standard for willful infringement to "objective recklessness," but the results of this change remain unclear.[229] The court should continue to limit the perverse incentives caused by this doctrine.[230]

The third legal change that would help promote the use of patents as technical sources is shortening the time before publication of the patent application. A number of respondents indicated that the current eighteen-month delay limits their ability to use patents to learn about state-of-the-art technologies, which supports arguments that the publication delay undermines the disclosure function of patents.[231] The American Inventors Protection Act of 1999 changed the default from publication only of issued patents to publication of applications eighteen months after filing.[232] One survey of intellectual

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[224] Madey v. Duke Univ., 307 F.3d 1351, 1362 (Fed. Cir. 2002) ("[S]o long as the act is in furtherance of the alleged infringer's legitimate business and is not solely for amusement, to satisfy idle curiosity, or for strictly philosophical inquiry, the act does not qualify for the very narrow and strictly limited experimental use defense.").

[225] *See* Ouellette, *supra* note 21, ¶¶ 31 & nn.87-89 (citing sources).

[226] *See* Nicholas M. Zovko, Comment, *Nanotechnology and the Experimental Use Defense to Patent Infringement*, 37 MCGEORGE L. REV. 129 (2006).

[227] *See, e.g.*, Eisenberg, *supra* note 1, at 224-26; Merges, *supra* note 1, at 164-65; Rai, *supra* note 1, at 139; Peter Lee, Note, *Patents, Paradigm Shifts, and Progress in Biomedical Science*, 114 YALE L.J. 659, 691-92 (2004).

[228] *See supra* notes 67-75 and accompanying text.

[229] *See supra* notes 72-74 and accompanying text.

[230] *Cf.* Lemley & Tangri, *supra* note 67, at 1119-24 (suggesting narrowing the definition of willfulness and limiting the damages associated with willful infringement).

[231] *See, e.g.*, Holbrook, *supra* note 5, at 143-45.

[232] Pub. L. No. 106-113, § 4502(a), 113 Stat. 1501A-561 (1999) (codified as amended at 35 U.S.C. § 122 (2006)). Because of various exceptions, the publication time can be even longer. For example, the Peng patent application described in Section III.A was based on a provisional application filed in October 2006, but it was not published until August 2010. *See supra* note 157. The corresponding research paper was published in August 2006, *see supra* note 158, so there is no reason to think any delay was necessary in this case.

property owners found that only five percent thought they were negatively affected by this change, suggesting that it did not have a significant impact on innovation incentives.[233] But eighteen months is still a long time in many fields, including nanotechnology. For example, in 2006 the journal *Nano Letters* averaged five weeks to acceptance and eight weeks to publication,[234] and *Science* and *Nature* also manage very rapid peer review.[235]

More rapid publication of patents is allowed under current law: "At the request of the applicant, an application may be published earlier than the end of such 18-month period."[236] Congress should consider mandating more rapid publication, either for all patents or just for those in fast-moving fields. The benefits of faster disclosure would have to be weighted against the costs to innovation—inventors may be concerned about their inventions being published long before the patent right is granted. This problem would be ameliorated by efforts to "cut[] the average overall processing time of a patent application from 35 months to 20 months by 2015,"[237] but there is still no evidence of whether the most efficient publication time is 18 months, 12 months, or immediately.

It would be a more straightforward reform for federal grant agencies like the NSF and NIH to change the rules for patents on federally funded research, which are allowed under the Bayh-Dole Act.[238] As I have summarized previously, the traditional innovation theories make little sense for Bayh-Dole patents—instead, the most plausible justification is commercialization (or prospect) theory, which argues that a property right is necessary to allow development of the

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[233] *See supra* note 98 and accompanying text. Concerns were raised, however, about the distributional effects of this shift. *See* Daniel K.N. Johnson & David Popp, *Forced out of the Closet: The Impact of the American Inventors Protection Act on the Timing of Patent Disclosure*, 34 RAND J. ECON. 96, 97 (2003).

[234] *See Faster Publication of Your High-Impact Research in Nano Letters*, 84 CHEMICAL & ENGINEERING NEWS 21 (2006).

[235] *See, e.g.*, *General Information for Authors*, SCIENCE, http://www.sciencemag.org/site/feature/contribinfo/prep/gen_info.xhtml (last visited Jan. 23, 2011) ("Reviewers are . . . asked to return comments within 1 to 2 weeks for most papers.").

[236] 35 U.S.C. § 122(b)(1)(A).

[237] Press Release, U.S. Patent & Trademark Office, Under Secretary of Commerce David Kappos Announces President Obama's FY 2012 Budget Request for the USPTO (Feb. 14, 2011), *available at* http://www.uspto.gov/news/pr/2011/11-12.jsp.

[238] 35 U.S.C. §§ 200-212.

invention into a commercial product.[239] Under this theory, early publication is actually beneficial, as it helps clearly demarcate the property right. Clearly written and quickly disclosed patents on federally funded research would be an important contribution to the technical literature.

### C. Improve Access to the Patent Literature

The previous two Sections described governmental changes that would improve the disclosure function of patents, but private parties like knowledge-promoting nonprofits, individual researchers, universities, and scientific journals could also improve the accessibility of patents in at least three ways. First, search engines should continue to improve patent indexing and searching, making it easier for researchers to locate relevant patents. Second, peer production systems like WikiPatents could encourage researchers to share enabling details about patents in addition to submitting relevant prior art. Third, universities and other recipients of public research funding could take the lead in setting the standards for robust patent disclosures. Finally, scientific journals could require authors to cite relevant patents. While any of these initiatives could occur without government intervention, the government could promote them through actions like providing seed money, funding conferences, or connecting the PTO website to private sites.

As described in the survey results in Section II.B, some nanotechnology researchers indicated that they would use patents if they were easier to find. Patents are now readily accessible through online search engines, and many surveyed researchers are finding patents through these methods.[240] Patents would be even more accessible, however, if they appeared alongside the technical literature in the most commonly used search engines.[241] For example, Wolfgang Glänzel and Martin Meyer suggest that the relatively high number of patent citations in chemistry publications is related to "the fact that the database *Chemical Abstracts* is the only large traditional bibliographic database in which also patents are indexed."[242] The Derwent Innovations Index is now "fully integrated in ISI Web of

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[239] *See* Lisa Larrimore Ouellette, Comment, *Addressing the Green Patent Global Deadlock Through Bayh-Dole Reform*, 19 YALE L.J. 1727, 1730-33 (2010).

[240] *See supra* notes 126-134 and accompanying text.

[241] *See* Fromer, *supra* note 7, at 586-87.

[242] Wolfgang Glänzel & Martin Meyer, *Patents Cited in the Scientific Literature: An Exploratory Study of 'Reverse' Citation Relations*, 58 SCIENTOMETRICS 415, 426 (2003).

Knowledge,"[243] and Google now provides patent results by default in Google Scholar searches (allowing one to see patent results in Google Scholar email alerts),[244] which may open the patent literature to additional researchers. Google could also offer links to related patents based on patents that are commonly viewed together.

A second way to improve access to the patent literature is through peer production.[245] The Peer To Patent program, which encourages public suggestions of relevant prior art for pending applications, was described in Section IV.A. Other platforms use peer production models to locate relevant prior art for granted patents, which could then be challenged through reexamination. WikiPatents functions like Wikipedia, enabling any registered user to add comments about published patents, with the goal "to become the crossroads at which inventors, engineers, scientists, . . . and other concerned members of the patent community openly share relevant and valuable information about specific patents . . . ."[246] The Electronic Frontier Foundation (EFF) Patent-Busting Project seeks public contributions to help invalidate the "worst free-speech and innovation crushing software" patents, and they have invalidated or narrowed eight of the ten patents they have taken on.[247]

All of these platforms have focused on locating relevant prior art, but they could also be used as a tool to share information about patents. For example, if a nanotechnology patent does not include the specific details of a nanofabrication recipe needed to reproduce the invention, a researcher who develops a working recipe could post it on the wiki page for that patent. Patent owners might even post improved recipes themselves, in the hope that more follow-on inventors will want to build on (and license) the original patent.

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243 *See Our Content*, WEB OF KNOWLEDGE, http://wokinfo.com/benefits/whywok/ourcontent/ (last visited Dec. 20, 2010).

244 *See supra* note 129 and accompanying text. Patent-specific RSS feeds can also be created through Google Patents. *See supra* note 127.

245 *See generally* Noveck, *supra* note 203, at 143-44 (providing other examples of peer production).

246 *Frequently Asked Questions for WikiPatents*, WIKIPATENTS, http://www.wikipatents.com/faq (last visited Dec. 25, 2010). Jeanne Fromer described the possibility of a "publicly annotated patent document." Fromer, *supra* note 7, at 592.

247 *See* Rebecca Jeschke, *EFF Tackles Bogus Podcasting Patent—And We Need Your Help*, ELEC. FRONTIER FOUND. DEEPLINKS BLOG (Nov. 19, 2009), https://www.eff.org/deeplinks/2009/11/eff-tackles-bogus-podcasting-patent-and-we-need-yo.

Universities and other recipients of public research funds could also play a role in improving the content of patent disclosures and making them more accessible. As mentioned previously, the Bayh-Dole Act allows recipients of public funding to patent their results on the theory that a property right in the idea is needed to incentivize further development.[248] But university professors were innovating and disclosing their research in scientific publications long before Bayh-Dole out of a desire for prestige in being the first to publish a new result.[249] Because the details of university inventions will be disclosed anyway, university technology transfer offices should take the lead in writing patent specifications that are clear and technically useful—university patents should contain at least as much information as the corresponding papers. Furthermore, universities could ask scientists who publish their work to list patents along with papers on their websites.[250]

A final way to make patents more accessible to researchers is by increasing the number of citations to patents in scientific journal articles. Although relatively few scientific articles currently cite patents,[251] some scientific publishers are working to increase scientific engagement with patents—for example, there is now a series of twenty-five journals focused on describing interesting patents in specific fields, with titles like *Recent Patents on Nanotechnology* and *Recent Patents on Anti-Cancer Drug Discovery*.[252] But scientific journals could do more to increase the accessibility of patents to researchers. A letter to the editor in *Nature* in 2009 noted the absence of patent citations in the top scientific journals:

> Why are patent citations so conspicuously absent across academic journals, with most even omitting formatting instructions for these in their author guidelines? Patents present novel, rigorously reviewed unpublished work, as well as providing an unmatched resource for detail.

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[248] *See supra* notes 238-239 and accompanying text.

[249] *See* Rai, *supra* note 1, at 92.

[250] *See supra* note 11 and accompanying text.

[251] *See* Glänzel & Meyer, *supra* note 242, at 418 ("On an average, about 13500 publications yearly are citing patents [from 1996 to 2000]. This is about 1.7% of all publications indexed in the SCI database.").

[252] *See Titles A-Z*, BENTHAM SCI. PUBLISHERS, http://www.bentham.org/a-z.htm (last visited Dec. 20, 2010). For an example article related to nanotechnology, see Rachel M. Frazier et al., *Recent Progress in Graphene-Related Nanotechnologies*, 3 RECENT PATENTS ON NANOTECHNOLOGY 164 (2009).

> We randomly selected one month (December 2008) and reviewed all citations in the reviews, articles and letters/reports in *Nature* (1,773 citations) and *Science* (1,367). These citations included textbooks, arXiv.org preprints and abstracts—but no patents.[253]

A response noted that "from a US perspective, this is unsound advice" because of willful infringement,[254] which is why this Article argues for scaling back this doctrine.[255] I agree with the original letter writers that "there should now be a more comprehensive citation of the patent literature in scientific publications."[256]

Scientific journals have played a key role in improving access to the data and code that researchers use for their publications.[257] They could play a similar role in improving access to patents by requiring researchers to cite relevant patents as well as publications, or by requiring a separate patent section in the citation list. Journals could also recommend that referees suggest patents that should be added to the citation list, just as referees currently frequently suggest technical publications that should be cited. Increased mixing of the scientific and patent literature would go a long way toward increasing scientists' engagement with patents.

## Conclusion

This Article has sought to reevaluate and add to the empirical literature on patent disclosure. These results show that the technical value of patent disclosures is greater than many legal scholars appreciated, but also that many patents probably fail to meet the existing disclosure requirements. This seems particularly true for patents based on the legal fiction of constructive reduction to practice—many experiments do not work the way one might expect, so it would require undue experimentation for a PHOSITA to create many speculative inventions. And disclosure problems will likely get worse with the likely switch to a first-to-file system, in which racing to

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[253] Donald F. Weaver & Christopher Barden, Correspondence, *Don't Overlook the Rigorously Reviewed Novel Work in Patents*, 461 NATURE 340, 340 (2009).

[254] David Piehler, Correspondence, *Legal and Practical Pitfalls in Making Use of Patents*, 462 NATURE 276 (2009).

[255] *See supra* Section IV.B.

[256] Weaver & Barden, *supra* note 253, at 340.

[257] *See supra* notes 39-42 and accompanying text.

the PTO (perhaps with an incomplete disclosure) becomes more important.[258]

The results of this Article suggest that disclosure requirements should be enforced, and even strengthened, and I argue that the best way to accomplish this is to get scientists even more engaged with the patent literature. For example, the PTO could send patents to scientists for peer review or patentees could be obligated to respond to enablement questions from other scientists. The patent literature should also become more accessible to scientists (including by removing legal barriers to its use). Bringing patents more in line with scientific norms will benefit both patent law and the scientific community.

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[258] The House and Senate have passed similar patent reform bills that both include first-to-file provisions. *See* Leahy-Smith America Invents Act, H.R. 1249, 112th Cong. (2011); Patent Reform Act of 2011, S. 23, 112th Cong. (2011).

# Appendix

**Table 1. Survey Questions and Answers from All 211 Respondents**

| **Question** | **Summary of Responses** |
|---|---|
| Which of the following best describes your current research environment? | Academic: 161 (76%)<br>Government: 27 (13%)<br>Industry: 16 (8%)<br>Nonprofit: 4 (2%) |
| Is your research primarily experimental or theoretical? | Experimental: 189 (90%)<br>Theoretical: 21 (10%) |
| Would you characterize the bulk of your research as basic or applied? | Primarily applied: 30 (14%)<br>Equal mix of basic and applied: 76 (36%)<br>Primarily basic: 104 (49%) |
| What is your highest degree? | Bachelor's: 2 (1%)<br>Master's: 3 (1%)<br>Ph.D. or other doctoral: 203 (96%) |
| From what department did you receive this degree? | Biomedical Engineering: 6 (3%)<br>Chemical Engineering: 10 (5%)<br>Chemistry or Biochemistry: 46 (22%)<br>Electrical Engineering: 19 (9%)<br>Materials Science: 12 (6%)<br>Mechanical Engineering: 7 (3%)<br>Physics or Applied Physics: 98 (46%) |
| In what decade did you receive this degree? | 1960s: 8 (4%)<br>1970s: 10 (5%)<br>1980s: 25 (12%)<br>1990s: 75 (36%)<br>2000s: 84 (40%)<br>2010s: 7 (3%) |
| Gender: | Female: 22 (10%)<br>Male: 181 (86%) |
| Do you currently work in the United States? | Yes: 158 (75%)<br>No: 51 (24%) |
| In the past two years, how many peer-reviewed papers have you published (including co-authored papers)? (If none, please enter "0") | Mean: 13.6<br>Min: 1 (N = 6)<br>Max: 100 (N = 1) |
| In the past two years, how many U.S. patent applications have been submitted on your inventions? (If none, please enter "0") | Mean: 2.1<br>Min: 0 (N = 86)<br>Max: 45 (N = 1) |

| | |
|---|---|
| If you discover a patentable invention in the future, would you like to have a patent on it? | Yes: 195 (92%)<br>No: 16 (8%) |
| Have you ever read any part of an actual patent (other than your own) for any purpose related to your research? | Yes: 135 (64%)<br>No: 76 (36%) |

***Notes:*** For details about the survey and how respondents were chosen, see *supra* notes 113-115 and accompanying text.

**Table 2. Comparing Respondents with Random Sample of All Researchers Contacted**

| **Measure** | **Respondents** | **Sample of Researchers** |
|---|---|---|
| Number | 211 | 100 (9% of 1078) |
| Papers (mean) | 13.6 | 20.2 |
| Patents (mean) | 2.1 | 2.3 |
| Academic | 76% | 76% |
| Government | 13% | 15% |
| Industry | 8% | 9% |
| Female | 10% | 10% |
| Outside U.S. | 24% | 28% |

***Notes:*** For details about how the random sample was measured, see *supra* note 118 and accompanying text. The only statistically significant difference between the respondents and the random sample is the number of papers published in the past two years: the survey respondents do not include the scientists who get their names on the highest number of papers. There is no significant correlation, however, between number of papers and whether a researcher reads patents, wants patents, thinks they are useful, or thinks they are enabled.

**Table 3. Responses from Researchers Who Have NOT Read a Patent**

| **Question** | **Responses** |
|---|---|
| **Why haven't you read any patents for research purposes? Please check all that apply:** | (% out of 76) |
| I do not think patents contain information that would be useful to me. | 65 (86%) |
| I do not know how to find relevant patents. | 22 (29%) |
| I am worried about negative legal effects of looking at patents. | 2 (3%) |
| I am not interested in patenting the results of my research. | 5 (7%) |
| Other: ________ | 17 (22%) |
| Do you anticipate that reading a patent later in your career might be useful? | Yes: 36 (47%)<br>No: 40 (53%) |

**Table 4. Responses from Researchers Who HAVE Read a Patent**

| **Question** | **Responses** |
|---|---|
| In the past two years, approximately how many patents have you read? | Mean: 14.69<br>Min: 0 (N = 5)<br>Max: 100 (N = 1) |
| **Please check ALL of the ways in which you have found a patent:** | (% out of 135) |
| A lawyer or someone from a legal department gave it to me. | 52 (38%) |
| Another scientific researcher gave it to me. | 45 (33%) |
| I found a citation to it in a paper or publication. | 37 (27%) |
| I searched on the US Patent and Trademark Office website. | 81 (60%) |
| I searched using Google Patents. | 61 (45%) |
| I found one by chance in another search. | 39 (29%) |
| Other: ________ | 11 (8%) |
| **Please check ALL of the reasons for which you have read a patent:** | (% out of 135) |
| Looking for legal information (either of the following two): | 95 (70%) |
| To determine whether my research might be infringing a patent. | 43 (32%) |
| To determine whether my research might be patentable. | 84 (62%) |
| Looking for technical information (any of the following three): | 94 (70%) |
| To learn how other researchers solved a particular technical problem I was facing. | 54 (40%) |
| To research a general scientific topic. | 60 (44%) |
| To browse information about cutting-edge technologies. | 22 (16%) |
| To cite the patent in one of my publications. | 17 (13%) |
| Other: ________ | 4 (3%) |
| If you have read a patent to gain scientific knowledge (either applied to a particular problem or regarding a general research topic), did you find useful information there? | Yes: 64 (60%)<br>No: 43 (40%) |
| Were the patents you read worded in such a way that you or another nanotech researcher could recreate the invention without additional information? | Yes: 48 (38%)<br>No: 79 (62%) |
| Do you worry that reading patents could have negative legal effects? | Yes: 6 (4%)<br>No: 128 (96%) |

**Table 5. Regression Coefficients for Survey Responses**

| | Papers | Patents | Want Patent | Read Patent | Useful | Enabled |
|---|---|---|---|---|---|---|
| Industry | -0.34*<br>(0.19) | 1.64***<br>(0.24) | — | 2.00*<br>(1.04) | 0.66<br>(0.71) | 1.30**<br>(0.63) |
| Experimental | -0.10<br>(0.17) | 1.08***<br>(0.40) | -0.24<br>(0.78) | 1.24**<br>(0.51) | 1.37<br>(0.97) | — |
| Basic Research | -0.03<br>(0.11) | -0.79***<br>(0.18) | -1.54**<br>(0.68) | -0.71**<br>(0.35) | -0.61<br>(0.46) | 0.22<br>(0.44) |
| Chemistry | 0.09<br>(0.15) | 0.02<br>(0.22) | -0.50<br>(1.20) | 1.28***<br>(0.48) | -0.72<br>(0.62) | -0.88*<br>(0.53) |
| Physics | -0.16<br>(0.13) | -0.25<br>(0.25) | -1.81*<br>(1.09) | 0.39<br>(0.39) | 0.05<br>(0.57) | -0.18<br>(0.50) |
| Time Since Ph.D. | 0.31***<br>(0.06) | 0.31***<br>(0.08) | 0.47**<br>(0.24) | 0.21<br>(0.17) | 0.60***<br>(0.21) | -0.14<br>(0.19) |
| Female | -0.29**<br>(0.14) | -0.17<br>(0.27) | -0.81<br>(0.66) | 0.15<br>(0.50) | -0.05<br>(0.72) | -0.21<br>(0.61) |
| Outside U.S. | 0.31**<br>(0.15) | -0.50*<br>(0.28) | -0.43<br>(0.52) | -0.42<br>(0.36) | 0.60<br>(0.59) | 0.27<br>(0.49) |
| N | 208 | 209 | 209 | 209 | 106 | 126 |

***Notes:*** The dependent variables for the quasi-maximum likelihood Poisson regressions in the first two columns are (1) the number of peer-reviewed papers published in the past two years; and (2) the number of U.S. patent applications submitted in the past two years. The dependent variables for the logistic regressions in the last four columns are dummy variables for (3) whether respondents want patents if they discover a patentable invention in the future; (4) whether they have ever read part of a patent (other than their own) for a research purpose; (5) whether respondents who have read patents to gain scientific knowledge found useful information; and (6) whether respondents who have read patents thought they were worded in such a way that the invention could be recreated by the respondent or another nanotech researcher without additional information (which is related to, but not identical to, the legal enablement requirement).

Independent variables (listed in separate rows) are (1) whether respondents work in industry; (2) whether their research is primarily experimental; (3) whether they primarily do basic research; (4) whether they received their Ph.D. in Chemistry, Biochemistry, or Chemical Engineering; (5) whether they received their Ph.D. in Physics or Applied Physics; (5) decades since Ph.D. (or other highest degree), where 0 = 2010s and 5 = 1960s; (6) whether respondents are female; and (7) whether respondents work outside the United States. The final row gives the number of responses used in each regression, which varies due to non-responses (N).

The "Industry" variable was omitted from the "Want Patent" regression because there are no industrial researchers who do not want a patent. Similarly, the "Experimental" variable was omitted from the "Enabled" regression because there are no non-experimentalists who believe patents are enabled.

Robust standard errors are in parentheses. Asterisks indicate statistical significance at the ***1%, **5%, and *10% levels.