PATENTING NANOTECHNOLOGY

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Universities and companies are rushing to the patent office in record numbers to patent nanotechnology inventions. This rush to the patent office is so significant that many law firms have established nanotechnology practice groups and the U.S. Patent and Trademark Office has now created a new technology class designed to track nanotechnology products. Three big differences between the emerging science of nanotechnology and other inventions make the role of patents more significant in this arena than elsewhere. First, this is almost the first new field in a century in which the basic ideas are being patented at the outset. In many of the most important fields of invention over the past century—computer hardware, software, the Internet, even biotechnology—the basic building blocks of the field were either unpatented or the patents were made available to all users by government regulation. In others, patents were delayed by interferences for so long that the industry developed free from their influence. In nanotechnology, by contrast, companies and universities alike are patenting early and often. A second factor distinguishing nanotechnology is its unique cross-industry structure. Unlike other new industries, in which the patentees are largely actual or at least potential participants in the market, a significant number of nanotechnology patentees will own rights not just in the industry in which they participate, but in other industries as well. This overlap may significantly affect their incentives to license the patents. Finally, a large number of the basic nanotechnology patents have been issued to universities, which have become far more active in patenting in the last twenty-five years. While universities have no direct incentive to restrict competition, their interests may or may not align with the optimal implementation of building-block nanotechnology inventions. The result is a nascent market in which a patent thicket is in theory a serious risk. Whether it will prove a problem in practice depends in large part on how efficient the licensing market turns out to be.

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I. THE RACE TO PATENT NANOTECHNOLOGY

Nanotechnology is the study and use of the unique characteristics of materials at the nanometer scale, between the classical large-molecule level to which traditional physics and chemistry apply and the atomic level in which the bizarre rules of quantum mechanics take effect. The unique behavior of materials at the nanoscale[1] offers intriguing possibilities for the cheap construction of rare molecules, the production of light and incredibly strong microfibers, and the production of ultrasensitive detectors.[2] Nanotechnology is at a speculative early stage; only a few nanotech[3] inventions have so far actually made it into commercial products. But the expectations surrounding the field are immense, ranging from a utopia of free energy and abundant materials[4] that will be one of the "major drivers of economic growth" in the foreseeable future[5] to fears of environmental catastrophe.[6]

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1. Steve Jurvetson offers one striking example of size-related changes in the behavior of materials: "[C]onsider the simple aluminum Coke can. If you take the inert aluminum metal in that can and grind it down into a powder of 20-30 nm particles, it will spontaneously explode in air. It becomes a rocket fuel catalyst." Steve Jurvetson, *Transcending Moore's Law with Molecular Electronics and Nanotechnology*, 1 NANOTECHNOLOGY L. & BUS. 70, 77 (2004); *see also* MARK RATNER & DANIEL RATNER, NANOTECHNOLOGY: A GENTLE INTRODUCTION TO THE NEXT BIG IDEA 7 (2003) (noting that nanoscale circuit components don't necessarily obey Ohm's law); *id.* at 56-57 (stating that the physical structure of carbon nanotubes makes them stronger and lighter than any other configuration of material).

2. For a general discussion of the science of nanotechnology accessible to the lay reader, see RATNER & RATNER, *supra* note 1.

3. In this Article, "nanotechnology" and "nanotech" will be used interchangeably.

4. *See* K. ERIC DREXLER, ENGINES OF CREATION (1986); NEAL STEPHENSON, THE DIAMOND AGE (1995).

5. NAT'L RESEARCH COUNCIL, SMALL WONDERS, ENDLESS FRONTIERS: A REVIEW OF THE NATIONAL NANOTECHNOLOGY INITIATIVE 2 (2002). Indeed, some predict that by 2015 nano-related goods and services will contribute $1 trillion to the global economy. *See* Raj Bawa, *Nanotechnology Patenting in the US*, 1 NANOTECHNOLOGY L. & BUS. 31, 36 (2004).

Whether nanotech is mostly hype or the wave of the future remains to be seen. But universities and companies seem to think there is something quite significant going on here, because they are rushing to the patent office in record numbers to patent nanotechnology inventions. This race to the patent office is so significant that more than a dozen law firms have established nanotechnology practice groups,[7] and the U.S. Patent and Trademark Office (PTO) has created a new technology cross-reference designed to track nanotechnology products.[8]

Some of those patents cover improvements in existing industries, notably semiconductors, where the continuous effort to shrink transistor size in order to increase the speed and memory of chips has led companies to develop sub-micron (i.e., nanoscale) components.[9] Others cover the commercial products so far enabled by the behavior of materials at the nanoscale, such as a transparent sunblock for windows, stain-resistant coatings for clothing or carpeting, improved drug delivery systems, and nano-level filtration systems that can separate pollutants or bacteria from air or water.[10] Still other patents—arguably the most important ones—cover the basic research and production tools or building blocks of nanotechnology,[11] such as atomic force microscopes that

6. *See* Glenn Harlan Reynolds, *Environmental Regulation of Nanotechnology: Some Preliminary Observations*, [2001] 31 Envtl. L. Rep. (Envtl. Law Inst.) 10681, 10681 (citing predictions that "rogue nanodevices will devour the planet").

7. Intellectual property law firms with separate nanotechnology groups include, among others: Sterne, Kessler, Goldstein & Fox; Brinks Hofer Gilson & Lione; Buchanan Ingersoll; Fenwick & West; Fish & Richardson; Fitzpatrick, Cella, Harper & Scinto; Foley & Lardner; Greenberg Traurig; DLA Piper Rudnick Gray Cary; Howrey; Pillsbury Winthrop Shaw Pittman; Preston Gates & Ellis; Sughrue Mion; and Townsend and Townsend and Crew.

8. *See Nanotech Cross-Reference Digest Is First Step in Improved Examination, PTO Official Says*, 69 Pat. Trademark & Copyright J. (BNA) No. 1695, at 25 (Nov. 12, 2004). This should help to deal with the difficulty of finding prior art in a technology that crosses many product disciplines. *See* Bawa, *supra* note 5, at 38 ("[S]earching for nanotechnology-related patents and publications is complicated relative to other technology areas."); Bhaven N. Sampat, *Examining Patent Examination: An Analysis of Examiner and Applicant Generated Prior Art* 25 (NBER Summer Institute, Working Paper, 2004), *available at* http://faculty.haas.berkeley.edu/wakeman/ba297tspring05/Sampat.pdf (noting that nanotech patents appear in hundreds of different PTO technology classes).

9. *See, e.g.*, Method & System for Optically Sorting &/or Manipulating Carbon Nanotubes, U.S. Patent No. 6,835,911 (filed Dec. 28, 2004); Thin Film Field Effect Transistor, U.S. Patent No. 6,720,617 (filed Apr. 13, 2004); Magnetic Storage Medium Formed of Nanoparticles, U.S. Patent No. 6,162,532 (filed Dec. 19, 2000).

10. *See, e.g.*, Nanocrystal-Containing Filtration Media, U.S. Patent No. 6,662,956 (filed Dec. 16, 2003); Nanoparticle-Based Permanent Treatments for Textiles, U.S. Patent No. 6,607,994 (filed Aug. 19, 2003); Ultraviolet Resistant Pre-Mix Compositions & Articles Using Such Compositions, U.S. Patent No. 6,337,362 (filed Jan. 8, 2002); Nanoparticles Containing the R(-) Enantiomer of Ibuprofen, U.S. Patent No. 5,718,919 (filed Feb. 17, 1998) (claiming a nanoparticle coating for a drug delivery system).

11. Siva Vaidhyanathan takes the "building-block" analogy a step further, asserting that nanotechnology patents are akin to patents on bricks. Siva Vaidhyanathan, *Nanotechnology and the Law of Patents: A Collision Course*, *in* NANOTECHNOLOGY AND

can manipulate individual molecules or carbon nanotubes that can be used to build very light, extremely strong products—anything from bulletproof shirts to space elevators.[12] This last category of technology may or may not have a commercial market itself but is necessary in order to produce downstream commercial products in the other two areas.

A recent study by Bhaven Sampat estimates that more than 3700 nanotechnology patents were issued in the United States between 2001 and 2003.[13] That's a significant number of patents for a technology that has so far produced few actual products. But, in fact, there are significant reasons to think that Sampat's numbers understate the pace of nanotechnology patenting.[14] First, he is intentionally conservative in his definition, classifying as nanotech inventions only patents whose claims include a restricted set of keywords that properly exclude terms like "nanosecond" that might pick up unrelated inventions.[15] This conservatism makes sense if the goal is to make sure that the patents identified are truly inventions in nanotechnology. But if the development of other new fields is any indication, there may be many issued patents that Sampat's study does not pick up because they use different terminology or employ the language in the specification rather than in the claims. Second, the pace of patenting seems to be accelerating. Replicating Sampat's methodology for 2004 shows that another 1929 patents were issued in 2004.[16] Third, and most important, the nearly three-year average delay between the filing of a patent application and the ultimate issuance of a patent[17] means that the patents Sampat studied were almost all based on inventions from the last century.[18] If the pace of nanotechnology invention is in fact accelerating,

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SOCIETY: A MULTIDISCIPLINARY EVALUATION (Geoffrey Hunt & Michael Mehta eds., forthcoming 2005), *available at* http://ssrn.com/abstract=740550.

12. *See infra* notes 56-62 and accompanying text (giving examples).

13. Sampat, *supra* note 8, at 24. Running the same search for the same dates in LexisNexis produces 5796 patents. It is unclear what explains the discrepancy.

14. For a much larger estimate, see Vaidhyanathan, *supra* note 11, at 7 (reporting 89,000 nanotechnology patents worldwide since 1976).

15. He does include "nanometer," which covers both clear nanotechnology inventions involving nanoscale gate size and nanofiltration and unrelated inventions dealing with optics (because the wavelength of visible light is measured in nanometers, regardless of the scale of the application). Altering Sampat's search to exclude "nanometer" reduces the number of patents substantially: only 56% of Sampat's issued patents, and 67% of the published applications, do not include any reference to "nanometer" in the claims. Communication from Michael F. Martin to Mark A. Lemley (Feb. 4, 2005) (on file with author). But while some of those patents are likely to be unrelated to nanotechnology as I have defined it, many will be true nanotech patents, especially in the semiconductor field.

16. LexisNexis search conducted January 14, 2005, using the same parameters as Sampat's search.

17. John R. Allison & Mark A. Lemley, *Who's Patenting What? An Empirical Exploration of Patent Prosecution*, 53 VAND. L. REV. 2099, 2118 (2000) (noting that patents spend 2.77 years in prosecution on average).

18. Some time must elapse between invention and filing, though it is generally no more than a year. Further, there is some reason to expect that nanotechnology patent

the growth of nanotechnology patents can be expected to continue in years to come. And it is clear that that pace is accelerating. The number of published patent applications in the United States that include the relevant terms in their claims has increased dramatically, as the following table demonstrates.[19]

Table 1. Published U.S. Patent Applications in Nanotechnology

Year	Published U.S. Applications
2001	403[20]
2002	1975
2003	2964
2004	1384 + 2458 = 3842[21]

II. WHAT MAKES NANOTECH PATENTS DIFFERENT?

The importance of nanotechnology patents is not simply a matter of numbers. Three differences between the emerging science of nanotechnology and other inventions make the role of patents more significant here than elsewhere.[22] First, unlike other fields, the building blocks of nanotechnology were patented at the outset. Second, the field has a unique cross-industry structure. And third, nanotech patents are held in surprisingly large proportion

applicants will take advantage of the continuation practice to delay the issuance of their patents, as biotechnology and pharmaceutical patentees have done, since there is as yet only a small market on which to capitalize. If the longer time that biotechnology and pharmaceutical patents spend in prosecution is any indication, the average time nanotech applications spend in the PTO may be closer to four or five years. *See id.* at 2155 tbl.10 (indicating that biotechnology inventions spend 4.72 years and pharmaceutical inventions 4.46 years in prosecution on average).

19. Table 1 represents my own calculations based on Sampat's search methodology. It is worth emphasizing that these numbers understate the actual number of patent applications filed in the PTO covering nanotechnology, because U.S. law permits applicants who do not intend to file abroad not to publish their applications. Nor do they include European nanotechnology patents. For a discussion of the latter, see Matthew Dixon, *European Patent Review*, 1 NANOTECHNOLOGY L. & BUS. 100 (2004).

20. Because U.S. patent law changed at the end of 1999 to require most applications to be published eighteen months after they were filed, applications were not published until the middle of 2001. As a result, this number likely understates by about forty percent the true number of applications filed during 2001 (specifically, those filed between January and May). Data from subsequent years suffer from no such bias.

21. The component numbers indicate the applications filed in the first six months and the last six months of 2004, respectively. The difference between the two periods provides further evidence of the acceleration.

22. While Barry Newberger argues that there are "no real doctrinal issues, certainly no burning doctrinal issues, in intellectual property protection and nanotechnology," Barry Newberger, *Intellectual Property and Nanotechnology*, 11 TEX. INTELL. PROP. L.J. 649, 649 (2003), I think he means only that there haven't yet been cases that present those issues. They are coming.

by universities. I explore these differences in this Part.

A. *Patents on Building Blocks*

This is nearly the first new field in almost a century in which the basic ideas were patented at the outset.[23] In a surprising range of fields of invention over the past century in what we might think of as "enabling" technologies[24]—computer hardware, software, the Internet, even biotechnology—the basic building blocks of the field were either unpatented, through mistake or because they were created by government or university scientists with no interest in patents, or the patents presented no obstacle because the government compelled licensing of the patents, or they were ultimately invalidated. In still other fields, including the laser, the integrated circuit, and polymer chemistry, basic building-block patents did issue, but they were delayed so long in interference

23. Two emerging technologies in which patents did play a prominent role were the airplane industry (between 1903 and 1917) and the radio industry (between 1912 and 1929). In both cases, the early patenting led to debilitating patent battles and arguably delayed the deployment of products. On airplanes, see George Bittlingmeyer, *Property Rights, Progress, and the Aircraft Patent Agreement*, 31 J.L. & ECON. 227 (1988); Peter C. Grindley & David J. Teece, *Managing Intellectual Capital: Licensing and Cross-Licensing in Semiconductors and Electronics*, 39 CAL. MGMT. REV. 8, 34 n.4 (1997). On radio, see W. RUPERT MACLAURIN, INVENTION AND INNOVATION IN THE RADIO INDUSTRY (1949); Grindley & Teece, *supra*, at 10-12. *But cf.* Ted Sabety, *Nanotechnology Innovation and the Patent Thicket: Which IP Policies Promote Growth?*, 1 NANOTECHNOLOGY L. & BUS. 262, 275-76 (2004) (suggesting that the large number of patent suits in the radio industry did not necessarily slow product introduction, perhaps because the government forced the creation of RCA to pool radio patents).

A third industry in which patents issued on building-block technologies is xerography, the making of copies using electrostatic charges to align dry ink. Chester Carlson, a patent attorney, invented xerography in 1938. Being a patent attorney, he immediately patented his invention and proceeded to patent a series of improvements. Fascinating Facts About the Invention of Xerography by Chester Carlson in 1938, http://www.ideafinder.com/history/inventions/xerography.htm (last visited Oct. 28, 2005). While one could dispute whether xerography is in fact an enabling technology in the sense I mean, it did open up a variety of fields and so is probably worth inclusion.

Notably, the patents in xerography were all held by Xerox, which effectively controlled the market for xerography for decades. Xerography is one of a very few inventions that was unambiguously made by the patent owner; no one else came close to developing a similar technology for well over a decade. *Id.* And even Xerox, Carlson's company, did not make a commercially successful copier until 1959, twenty-one years after his invention and the year his basic patent expired.

24. By "enabling" technology, I mean to refer not merely to important new ideas or even ideas that create a new market, but only to technological breakthroughs that facilitate a wide range of different exploitations. Obviously, the term is not capable of precise definition. It shares significant characteristics with what Brett Frischmann calls "infrastructure" technologies—those that may be consumed nonrivalrously, whose social value is driven primarily by downstream use, and for which there are a wide spectrum of such uses. Brett M. Frischmann, *An Economic Theory of Infrastructure and Commons Management*, 89 MINN. L. REV. 917, 919 (2005).

proceedings that the industry developed in the absence of enforceable patents.

In each of these fields this was largely the result of inadvertence rather than patent policy.[25] Indeed, the history of emergent fields in the last eighty years is a remarkable story in which invention after invention was put into the public domain, freely licensed because of government or university policy, subjected to inventorship disputes for decades, or otherwise avoided patenting during the formative years of the industry. In this Subpart, I discuss some of the more salient examples.

Computers. The computer was largely the result of military research projects during World War II, and government-sponsored research was not generally patented at that time. Even if it were, the military applications of the early computers meant that secrecy, not public disclosure, was the order of the day. The inventor of the computer, John Atanasoff, and his employer, Iowa State University, thought about seeking patent protection but never did so.[26] AT&T did obtain basic patents on the transistor, an important component of later computers,[27] but licensed them broadly at low royalty rates under an antitrust consent decree that also precluded it from entering the market for transistors itself.[28] Similarly, antitrust consent decrees compelled IBM to grant

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25. Patent law does prohibit the patenting of abstract ideas, O'Reilly v. Morse, 56 U.S. (15 How.) 62, 112 (1853), and this bar sometimes serves to prevent early-stage patenting of broad concepts. *See* Dan L. Burk & Mark A. Lemley, *Policy Levers in Patent Law*, 89 VA. L. REV. 1575, 1642-44 (2003) (discussing the doctrine). But it would not have prevented the patenting of basic technologies in any of the industries I discuss in the text.

26. There is substantial dispute as to who was the true first inventor of the computer. For a strong argument that it was John Atanasoff, a professor at Iowa State University during World War II, see ALICE R. BURKS & ARTHUR W. BURKS, THE FIRST ELECTRONIC COMPUTER: THE ATANASOFF STORY (1988). *See also* CLARK R. MOLLENHOFF, ATANASOFF: FORGOTTEN FATHER OF THE COMPUTER (1988). The Burks argue that he had completed the computer. BURKS & BURKS, *supra*, at 277-78. Atanasoff himself says that it was ready for patenting and that he engaged a patent attorney to patent it, with the rights assigned to Iowa State University. Nonetheless, it was never patented. He writes:

> During the spring and summer of 1942, I continued to work with [Iowa State] and Mr. Trexler to get the patent under way. There always seemed to be some reason why it should be put off, however, and put off it was. The patent was never applied [for] by Iowa State College, probably due to short-term financial considerations.

J.A.N. LEE, COMPUTER PIONEERS 37 (1995).

The Electronic Numerical Integrator and Computer (ENIAC) was developed by the Ballistics Research Laboratory in Maryland to assist in the preparation of firing tables for artillery. It was completed at the University of Pennsylvania's Moore School of Electrical Engineering in November 1945. While it was long treated as the first computer and was in fact patented, the patent was held unenforceable on the ground that it was improperly derived from Atanasoff's work. Honeywell Inc. v. Sperry Rand Corp., 180 U.S.P.Q. (BNA) 673, 686, 747-50 (D. Minn. 1973).

Other significant advances in computing came from the unpatented development of radar analysis and display systems by the U.S. and British militaries during the war.

27. Circuit Element Utilizing Semiconductive Material, U.S. Patent No. 2,569,347 (filed June 26, 1948).

28. United States v. AT&T, 552 F. Supp. 131, 136 (D.D.C. 1982). For this argument,

nonexclusive licenses to all of its computer-equipment patents at reasonable royalties.[29]

Software and the Internet. Basic software inventions were not patented, because during the 1960s, 1970s, and early 1980s, the courts took the position that software was not patentable at all.[30] The basic protocols of the Internet are in the public domain because they were developed with federal funding and at universities in the late 1960s and early 1970s, and public inventions were not generally patented at that time.[31] Subsequent basic Internet inventions, such as the World Wide Web, generally were not patented either because they were created by individuals at public institutions that did not think patents were necessary or appropriate[32] or because the inventors believed software still wasn't patentable.[33] The Internet story isn't perfectly clear—patentees pop up

see Robert P. Merges & Richard R. Nelson, *On the Complex Economics of Patent Scope,* 90 COLUM. L. REV. 839, 896 (1990); Sabety, *supra* note 23, at 269.

29. United States v. IBM Corp., No. 72-344, 1956 U.S. Dist. LEXIS 3992, at *25-26 (S.D.N.Y. Jan. 25, 1956). *But cf.* David McGowan, *Between Logic and Experience: Error Costs and* United States v. Microsoft Corp., 20 BERKELEY TECH. L.J. 1185 (2005) (arguing that the consent decrees against IBM did not cause the openness of basic *software* inventions).

30. *See, e.g.*, Parker v. Flook, 437 U.S. 584 (1978); Gottschalk v. Benson, 409 U.S. 63 (1972). For a brief discussion of how that rule was eroded into nonexistence, see Julie E. Cohen & Mark A. Lemley, *Patent Scope and Innovation in the Software Industry,* 89 CAL. L. REV. 1, 8-11 (2001).

31. That is no longer true today, in large part because of the Bayh-Dole Act of 1980, 35 U.S.C. §§ 200-212 (2005), which permits universities and others receiving federal funding for research to patent the results of that funded research.

32. For example, Tim Berners-Lee, the inventor of the World Wide Web, was employed by CERN, a government-sponsored high energy research physics laboratory in Europe. He developed the Web in order to facilitate communication between physicists, and both he and CERN treated it as a tool for use in their primary work rather than as an end product in itself. In any event, as Berners-Lee later put it:

> [H]ad the technology been proprietary, and in my total control, it would probably not have taken off. The decision to make the Web an open system was necessary for it to be universal. You can't propose that something be a universal space and at the same time keep control of it.

Tim Berners-Lee, Frequently Asked Questions, http://www.w3.org/People/Berners-Lee/FAQ.html (last visited Oct. 22, 2005). For a discussion of the development of the Web, see Timothy Wu, *Application-Centered Internet Analysis*, 85 VA. L. REV. 1163 (1999).

33. Mosaic is widely recognized as the first web browser with graphics capability. *See* KATIE HAFNER & MATTHEW LYON, WHERE WIZARDS STAY UP LATE: THE ORIGINS OF THE INTERNET 258 (1996). The first version of Mosaic was released in early 1993 by Marc Andreesen and Eric Bina, who were then employees of the National Center for Supercomputing Applications (NCSA), an affiliate of the University of Illinois, Urbana-Champaign. *See* Marc Andreessen & Eric Bina, *NCSA Mosaic: A Global Hypermedia System*, 4 INTERNET RES.: ELECTRONIC NETWORKING APPLICATIONS & POL'Y 7, 7 (1994). Although the University of Illinois never filed patent applications on Mosaic, this was not the result of any policy generally unfavorable toward intellectual property. On the contrary, the University was vigorous in its enforcement of copyright in Mosaic. *See, e.g.*, Procedures for Licensing NCSA Mosaic (July 19, 1995), *available at* http://archive.ncsa.uiuc.edu/SDG/Software/Mosaic/License/LicenseInfo.html.

periodically claiming to own pieces of the Internet[34]—but as a general matter people have been able to use the basic protocols of the Internet free of patent liability.[35]

Biotechnology. Basic inventions in biotechnology also largely ended up in the public domain, a fact that is somewhat more surprising given the importance of patents today in that industry.[36] A variety of different facts combined to produce this arguably fortuitous result. As a product of nature, human DNA is ineligible subject matter for patenting. Even nonnaturally occurring biological materials were not clearly patentable until the Supreme Court's decision in *Diamond v. Chakrabarty*.[37] Methods for isolating DNA, however, would presumably have been patentable even before that time. Yet, the earliest patent including a claim that mentions DNA did not issue until 1976,[38] over twenty years after DNA's structure was first described.[39] A more plausible explanation is that the basic research on the structure of DNA occurred quite early, well before universities were involved in patenting. Watson and Crick did their work in the early 1950s. Holley, Khorana, and

The best explanation for why the University of Illinois did not apply for patents on Mosaic is probably that prior to 1995 it was not clear to those unversed in the field that software inventions were subject matter eligible for patenting. This speculation finds some support in the chronology of events that unfolded in 1995, after Andreessen and Bina left NCSA to found Mosaic Communications Corporation (later Netscape Communications Corporation). On June 2, 1995, the U.S. Patent and Trademark Office issued its first set of proposed guidelines for examining software-patent applications. *See* Request for Comments on Proposed Guidelines for Computer-Implemented Inventions, 60 Fed. Reg. 28,778 (June 2, 1995). On August 15, 1995, Netscape's first patent application on browser technology was filed. *See* Browser Having Automatic URL Generation, U.S. Patent No. 5,978,817 (filed Nov. 2, 1999) (claiming priority from abandoned patent application number 08/515,189, filed Aug. 15, 1995). But the basic technology, which was developed at NCSA, was not patented.

34. Among the many such claims are British Telecom's claim to own a patent covering hyperlinks, *see* British Telecomms. v. Prodigy Commc'ns Corp., 217 F. Supp. 2d 399 (S.D.N.Y. 2002), DE Technologies' claim to own a patent covering all international electronic commerce, *see* Andrew Park, *A Patent Challenge for Dell*, BUSINESSWEEK ONLINE, Nov. 3, 2004, http://www.businessweek.com/technology/content/nov2004/ tc20041 34934_tc119.htm, Acacia's claim to own patents covering the provision of video on demand, *see In re* Acacia Media Techs. Corp., Patent Litig., 360 F.Supp.2d 1377 (J.P.M.L. 2005), and CL/Forgent's claim to own a patent covering data compression, *see In re* Compression Labs, Inc., Patent Litig., 360 F. Supp. 2d 1367 (J.P.M.L. 2005).

35. In fact, the Internet Engineering Task Force, which sets Internet standards, forbade patents on its standards until recently. *See* Mark A. Lemley, *Intellectual Property Rights and Standard-Setting Organizations*, 90 CAL. L. REV. 1889, 1893 (2002) (discussing the change). The new policy is available at S. Bradner, The Internet Standards Process: Revision 3 (Oct. 1996), http://www.ietf.org/rfc/rfc2026.txt (last visited Oct. 23, 2005).

36. On the importance of biotech patents, see Dan L. Burk & Mark A. Lemley, *Biotechnology's Uncertainty Principle,* 54 CASE W. RES. L. REV. 691 (2004).

37. 447 U.S. 303 (1980).

38. *See* Biologically Active Material, U.S. Patent No. 3,931,397 (filed Nov. 8, 1973).

39. *See* J.D. Watson & F.H.C. Crick, *Molecular Structure of Nucleic Acids*, 171 NATURE 737 (1953).

Nirenberg won a Nobel Prize in 1968 for their work on the genetic code.[40] All were academic scholars. At that time, universities had strong norms against patenting, particularly in medical inventions.[41]

That norm may also have influenced the United Kingdom's Medical Research Council's and National Research and Development Corporation's decision not to apply for patents on Kohler and Milstein's invention of monoclonal antibodies.[42] Shortsightedness also played a role in that decision, however. The Corporation concluded that "the general field of genetic engineering is a particularly difficult area from the patent point of view and it is not immediately obvious what patentable features are at present disclosed" and that "[i]t is certainly difficult for us to identify any immediate practical applications which could be pursued as a commercial venture."[43]

Even once that norm began to change, university patents on basic building blocks in biotechnology were generally licensed freely. For example, Cohen and Boyer did obtain a fundamental patent on their 1973 invention of a method of creating chimeric DNA sequences, Axel received one on his roughly contemporaneous methods of inserting genes into a cell, and both licensed their patents for significant revenue.[44] But largely because they were funded by the

40. *See* Professor P. Reichard, Member of the Nobel Committee for Physiology or Medicine of the Royal Caroline Institute, Presentation Speech: The Nobel Prize in Physiology or Medicine 1968, http://www.nobel.se/medicine/laureates/1968/press.html (last visited Sept. 26, 2005).

41. *See* Sally Smith Hughes, *Making Dollars Out of DNA: The First Major Patent in Biotechnology and the Commercialization of Molecular Biology, 1974-1980*, 92 ISIS 541 (2001). In her study, she describes how academic doctors had observed private norms against patenting at least as far back as the American Medical Association's Code of Ethics of 1847. *See id.* at 547. Harvard, for example, had put in writing in 1934 a policy dedicating faculty research in public health and therapeutics to the public. *See id*. Moreover, "[m]ost universities of the day lacked the capacity to evaluate, let alone exploit, the commercial potential of faculty research findings." *Id.* at 546. Indeed, even at Stanford, which had the capacity (having formally established its licensing program in 1970) and an institutional history of "close interactions with companies in the region," *id.* at 547, Neils Reimers, the first administrator of the university's Office of Technology Licensing, had a difficult time gathering political support for the patent applications, even from Cohen and Boyer themselves. *See id.* at 549 (recounting Reimers's recollection "that he had to talk to Cohen 'like a Dutch uncle' in obtaining his permission to file a patent application"); *see also* DAVID C. MOWERY ET AL., IVORY TOWER AND INDUSTRIAL INNOVATION: UNIVERSITY-INDUSTRY TECHNOLOGY TRANSFER BEFORE AND AFTER THE BAYH-DOLE ACT 4 (2004) ("Through much of the twentieth century U.S. universities were ambivalent about direct involvement in patenting and licensing."). For a general discussion of the norm of openness in academic research, see Arti Kaur Rai, *Regulating Scientific Research: Intellectual Property Rights and the Norms of Science*, 94 NW. U. L. REV. 77 (1999).

42. *See* G. Kohler & C. Milstein, *Continuous Cultures of Fused Cells Secreting Antibody of Predefined Specificity*, 256 NATURE 495 (1975).

43. ROBERT PATRICK MERGES & JOHN FITZGERALD DUFFY, PATENT LAW AND POLICY: CASES AND MATERIALS 747 (3d ed. 2002).

44. The Cohen-Boyer patents went on to earn Stanford and the University of California over $250 million before they expired in 1997. *See* Hughes, *supra* note 41, at 570

federal government before the passage of the Bayh-Dole Act, they granted nonexclusive licenses to all comers,[45] meaning that their patents raised the cost of practicing biotechnology but did not prevent anyone from entering the downstream market. Further, even when companies began obtaining and enforcing biotechnology patents in earnest, a number of early Federal Circuit decisions gave biotechnology patents a narrow scope, making it impossible to patent a broad genus based even on pioneering work and leaving the development of that genus open to others.[46]

Finally, polymerase chain reaction (PCR), one significant biotechnology building block that was patented by a private corporation,[47] did generate substantial revenue for the patent owner for many years. However, the core patent was ultimately held unenforceable for inequitable conduct.[48]

Integrated circuits. The integrated circuit was itself an improvement in the field of computing, a way of building transistors (an invention discussed above)

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n.77.

45. *See* Bernard Wysocki, Jr., *College Try: Columbia's Pursuit of Patent Riches Angers Companies*, WALL ST. J., Dec. 21, 2004, at A1 (noting that the National Institutes of Health required Axel to license his patents nonexclusively and at a reasonable royalty).

46. *See, e.g.*, *In re* Goodman, 11 F.3d 1046, 1052 (Fed. Cir. 1993); Fiers v. Revel, 984 F.2d 1164, 1170-71 (Fed. Cir. 1993); Amgen v. Chugai, 927 F.2d 1200 (Fed. Cir. 1991).

47. Kary Mullis first conceived PCR while working at Cetus Corporation. *See* Kary B. Mullis, *The Polymerase Chain Reaction (Nobel Lecture)*, 33 ANGEWANDTE CHEMIE INT'L ED. ENG. 1209 (1994). Although a friend suggested that he "resign [his] job, wait a little while, make it work, write a patent, and get rich," *id.* at 1212, Mullis "responded weakly to [his friend's] suggestion," expressing concern that if PCR "turned out to be commercially successful [Cetus] would have lawyers after [him] forever." *Id.* at 1213.

Mullis and Cetus Corporation began filing patent applications on PCR in early 1985. *See* Process for Amplifying Nucleic Acid Sequences, U.S. Patent No. 4,683,202 (filed Oct. 25, 1985) [hereinafter '202 patent] (claiming priority from abandoned application number 716,975, filed Mar. 28, 1985). Numerous continuation and continuation-in-part applications were filed claiming priority to the '202 patent, including Purified Thermostable Enzyme, U.S. Patent No. 4,889,818 (filed June 17, 1987) [hereinafter '818 patent].

48. The successors in title to the '202 patent and its progeny, F. Hoffman-La Roche, Roche Molecular Systems Inc., and Applied Biosystems, had achieved a remarkable measure of success in licensing PCR technology before the '818 patent was ruled unenforceable for inequitable conduct on the Patent and Trademark Office in 1999. *See* Hoffmann-La Roche, Inc. v. Promega Corp., No. C-93-1748 VRW, 1999 WL 1797330, at *28 (N.D. Cal. Dec. 7, 1999). Although the Federal Circuit reversed in part, *see* Hoffman-La Roche, Inc. v. Promega Corp., 323 F.3d 1354 (Fed. Cir. 2003), on remand the district court again held the '818 patent unenforceable, but refused to hold its family of patents unenforceable under the doctrine of infectious unenforceability, *see* Hoffman-La Roche, Inc. v. Promega Corp., 319 F. Supp. 2d 1011 (N.D. Cal. 2004).

The effect of these decisions on the market for PCR-related products is difficult to determine. For example, some suppliers apparently began selling Taq polymerase, an enzyme claimed in the '818 patent, without a license after the initial district court judgment in 1999. *See* Aileen Constans, *Courts Cast Clouds over PCR Pricing*, SCIENTIST, Sept. 3, 2001, at 1, 22. But there are other patents covering PCR that have not been held unenforceable. *See* Applera Corp. v. MJ Research Inc., 372 F. Supp. 2d 233, 234-35 (D. Conn. 2005) (reporting jury verdict finding patents valid and infringed).

directly into a computer chip by using charged silicon, a semiconductor. The invention opened up not just computing but also calculators, cell phones, and a host of other portable electronic devices. But because two different inventors working independently developed the integrated circuit at about the same time (1971), the patents were put into interference. Gary Boone was ultimately declared the winner, but not until 1999, twenty-eight years after the first patent application was filed.[49]

Lasers. The laser was invented in 1957 in a physics laboratory at Columbia University that was working with "masers," which stimulated microwaves until they were emitted in a coherent beam. A team of professors at Columbia (Charles Townes and Arthur Schawlow) and a graduate student working with them (Gordon Gould) submitted separate patent applications for an "optical maser," or laser.[50] The applications were put into interference, which was then appealed within the Patent Office and eventually to the court of appeals. Townes and Schawlow were declared the first inventors in 1966.[51] But Gould continued to pursue patents on his invention and obtained a fundamental patent in 1977. He enforced it in court, but he didn't ultimately prevail until 1988, thirty-one years after the invention of the laser and nearly thirty years after it was put into practical use.[52]

Polymer chemistry. The development of polypropylene was a true enabling technology, opening up a variety of fields from fabrics to plastics. Who actually first developed polypropylene was a matter of considerable dispute, however. The resolution depended on whether the first crystalline form or the later development of an actual usable form counted as the first true invention. Multiple patent applicants claimed to be first, and the resolution of the interference did not occur until 1982, twenty-eight years after the 1954 invention of polypropylene.[53]

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49. Gary W. Boone first filed a patent application disclosing an integrated circuit on July 19, 1971. *See* U.S. Patent No. H1970 (filed July 19, 1971). Interference No. 102,598 was declared on March 27, 1991, and the Board of Patent Appeals and Interferences (BPAI) finally reconsidered its earlier decision of priority on May 10, 1996. *See* Hyatt v. Boone, 146 F.3d 1348, 1351 n.1 (Fed. Cir. 1998). An opinion in the last appeal of the BPAI's decision awarding priority to Boone was issued on August 26, 1998. *See id.*

50. For a detailed discussion, see NICK TAYLOR, LASER: THE INVENTOR, THE NOBEL LAUREATE, AND THE THIRTY-YEAR PATENT WAR (2000).

51. Gould v. Schawlow, 363 F.2d 908 (C.C.P.A. 1966).

52. Kenneth Chang, *Gordon Gould, 85, Figure in Invention of the Laser*, N.Y. TIMES, Sept. 20, 2005, at A27.

53. The multiparty interference was declared by the BPAI on September 9, 1958. *See* Standard Oil Co. v. Montedison, S.p.A, 494 F. Supp. 370, 374 (D. Del. 1980). The BPAI issued its final opinion on priority on November 29, 1971. *See id.* at 375. The patent was filed on June 8, 1955, and issued on February 6, 1973. *See id.* at 374 n.5; *see also* U.S. Patent No. 3,715,344 (filed June 8, 1955). The BPAI decision was appealed to the U.S. District Court for the District of Delaware, *see Standard Oil Co.*, 494 F. Supp. 370, and then to the Third Circuit, *see* Standard Oil Co. v. Montedison, S.p.A., 664 F.2d 356 (3d Cir. 1981).

Television. In yet another industry, television, the invention was immediately patented, but disputes over whether the patentee, Philo Farnsworth, was the true inventor prevented him from licensing the patents until they had almost expired. Unlike the integrated circuit, the laser, or polypropylene, the patents were not delayed by interference proceedings, but Farnsworth found himself unable to license (and apparently unwilling to enforce) them because of the inventorship dispute.[54]

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The sum of all these stories is rather remarkable: for one reason or another, the basic building blocks of what might be called the enabling technologies of the twentieth century—including the computer, software, the Internet, and biotechnology—all ended up in the public domain. Whether through a policy decision, a personal belief, shortsightedness, government regulation, or invalidation of the patent, no one ended up owning the core building blocks of these technologies during their formative years. This does not mean that there were no patents in these fields, or even that there were no major patents—far from it. But the patents that were obtained and enforced in these fields tended to cover implementations of or improvements to the basic building-block technologies. If patents were granted on the basic building blocks, it was often only after decades of litigation over inventorship.

In nanotech, by contrast, companies and universities alike are patenting early and often. This is the age of patents. There is no government-mandated license, no university policy against patenting, and no question about patentable subject matter to slow the flood of patents. While some of these patents are on industry-specific improvements to existing work above the nanoscale, particularly in the semiconductor industry, other patents cover basic building blocks in nanotechnology. Indeed, many of the most basic ideas in nanotechnology are either already patented or may well end up being patented.[55] For example, patents have issued on carbon nanotubes,[56] semiconducting nanocrystals,[57] light-emitting nanocrystals,[58] metal oxide

54. *See* EVAN I. SCHWARTZ, THE LAST LONE INVENTOR: A TALE OF GENIUS, DECEIT, AND THE BIRTH OF TELEVISION (2002); Fascinating Facts About the Invention of the Television by Philo T. Farnsworth in 1927, http://www.ideafinder.com/history/inventions/story085.htm (last visited Oct. 22, 2005).

55. Because patents can spend an unlimited time in the patent office, *see* Mark A. Lemley & Kimberly A. Moore, *Ending Abuse of Patent Continuations*, 84 B.U. L. REV. 63, 64 (2004), and because many such patent applications will not be published, either because they were filed before 1999 or because they are filed only in the United States, 35 U.S.C. § 122(b)(2)(B) (2005), it is impossible to tell for certain whether currently unpatented technologies will ultimately be patented.

56. U.S. Patent No. 6,683,783 (filed Mar. 6, 1998); U.S. Patent No. 5,747,161 (filed Oct. 22, 1996); U.S. Patent No. 5,424,054 (filed May 21, 1993).

57. U.S. Patent No. 5,505,928 (filed Apr. 21, 1994); *see also* U.S. Patent No. 6,268,041 (filed Dec. 15, 1998) (covering silicon or germanium nanocrystals of consistent

nanorods,[59] atomic force microscopes,[60] a method of making a self-assembling nanolayer,[61] and a method of producing nanotubes through chemical vapor deposition.[62] Indeed, there are only a few basic building blocks in nanotechnology that are *unpatented*, notably buckminsterfullerene.[63] It is too early to tell for sure how significant nanotech building-block patents will turn out to be or how they will be enforced, but it is quite possible that more of the fundamental building blocks of nanotechnology will be patented than in any of the industries discussed above. Furthermore, nanotechnology may represent the future of innovation in this respect.

B. *Cross-Industry Patents*

A second factor driving the importance of patents in nanotechnology is the field's unique cross-industry structure. Nanotech is not confined to a single field of endeavor, but exploits the peculiar properties of matter at the nanoscale across many different fields of modern engineering. Thus, a basic nanotechnology patent may have implications for semiconductor design, biotechnology, materials science, telecommunications, and textiles, even though the patent is held by a firm that works in only one of these industries. To be sure, many nanotechnology inventions exist comfortably within a single industry—this is notably true of semiconductors—and don't seem to have significant cross-industry applications. But many others take advantage of the unique physical properties of nanoscale materials to put things to radically different uses. Semiconductor companies may use organic self-assembly to create electronic components in silicon that traditionally required mechanical deposition, for example.[64] Unlike other new industries, in which the patentees are largely actual or at least potential participants in the market, a significant number of corporate nanotechnology patentees will own rights not just in the industry in which they participate, but in other industries as well.[65]

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size).

58. U.S. Patent No. 6,322,901 (filed Nov. 13, 1997).

59. U.S. Patent No. 5,897,945 (filed Feb. 26, 1996).

60. U.S. Patent No. 5,833,705 (filed Sept. 20, 1996); U.S. Patent No. 4,724,318 (filed Aug. 4, 1986).

61. U.S. Patent No. 5,286,571 (filed Aug. 21, 1992).

62. U.S. Patent No. 6,346,189 (filed Aug. 14, 1998).

63. Buckminsterfullerene, or carbon-60, which was discovered in 1985 by Curl, Smalley, and Kroto, *see* H.W. Kroto et al., *C60: Buckminsterfullerene*, 318 NATURE 162 (1985), is itself unpatented and might well be unpatentable as a naturally occurring product of nature. Over 100 patents on *implementations* of the molecule have issued, however. *See* Fullerene Patent Database, http://www.godunov.com/Bucky/Patents.html (last visited Sept. 26, 2005).

64. Jurvetson, *supra* note 1, at 83.

65. The fact that Sampat's study identified patents in 253 different international patent classes is some indication of the breadth of the technology involved. *See* Sampat, *supra* note

These cross-industry rights may significantly affect their incentives to license the patents, as I discuss below. Certainly, the experience of the semiconductor, Internet, and information technology industries has been that patentees who do not participate in the market are more likely to sue to enforce their patents than those who are in the market.[66] Whether or not the cross-industry nature of nanotechnology patents increases the likelihood of suit, at a minimum it means that companies looking to clear patent rights in nanotechnology must not only look to inventors in their own field, but must also search in widely disparate fields.

C. *The Role of Universities*

The third significant fact unique to nanotechnology patents is that they are held in surprisingly large proportion by universities. Universities and public-interest foundations generally hold only about one percent of the patents issued in the United States each year,[67] but they hold a grossly disproportionate share of nanotech patents. Of the nanotechnology patents identified using Sampat's methodology, at least twelve percent are assigned to universities, a proportion that is a dozen times as high as the proportion of university patents in general.[68] Table 2 illustrates this phenomenon in more detail.[69]

8, at 25.

66. There are numerous examples of both small licensing shops and large companies that have essentially left the market but still file patent lawsuits in these industries. For example, Jerome Lemelson is famous for having licensed his patents aggressively, and Texas Instruments (TI) is one of the most aggressive licensors of patents in the semiconductor industry. Lemelson did not make any products himself and therefore didn't need cross-licenses from anyone. TI, while still a player in many markets, litigated primarily in the area of large-scale integrated circuits, in which it did not have significant sales at the time of the lawsuits. Empirical evidence suggests that small companies are much more likely to enforce their patents than large ones, John R. Allison et al., *Valuable Patents*, 92 GEO. L.J. 435, 465-70 (2004), but does not provide a way to distinguish small market participants from nonparticipants.

67. Allison & Lemley, *supra* note 17, at 2128.

68. The one other industry with a comparable proportion of university patents is biotechnology, in which universities hold between thirteen and eighteen percent of the issued patents. David E. Adelman & Kathryn L. DeAngelis, Mapping the Scientific Commons: Biotechnology Patenting from 1990 to 2004, at 14 (Oct. 19, 2005) (unpublished manuscript) (on file with author).

69. My research assistant and I searched these patents for the terms "university," "college," "trustee," or "foundation" in the assignee field. We found that 664 of the 5536 issued nanotechnology patents satisfied the criteria. These criteria are possibly both over- and underinclusive—overinclusive because the term "foundation" or "trustee" in the name of a patent owner may sometimes signal a private foundation rather than a university nonprofit, and underinclusive because there may be university-controlled patents that are held by entities with different names. For example, the patent owner and licensor of the University of Colorado's patents is Competitive Technologies, Inc.

Interestingly, we found a much smaller percentage (381 of 9184, or only 4.1%) of published patent applications that met these criteria. But that appears to be a statistical

Table 2. Nanotechnology Patents Assigned to Universities

Issue Year	Number of Nanotech Patents	Number Assigned to Universities	Percentage Assigned to Universities
2001	1077	148	13.7%
2002	1217	138	11.3%
2003	1534	175	11.4%
2004	1708	203	11.9%
Total	5536	664	12.0%

Further, the university-owned patents are logically more likely to be upstream patents on building blocks that are of critical importance to innovation than particular downstream implementations of a technology. This reasoning is harder to test empirically, but it seems to be borne out when one looks at the specific patents being granted to universities. Indeed, of the ten foundational patents identified above,[70] seven are owned by universities,[71] and sixty percent of the publicly announced nanotechnology patent licenses in 2003 were granted by universities.[72]

There are several likely reasons for the comparative dominance of universities in nanotech patenting. First, the technology is still in its infancy, and many of the patents that have issued so far—certainly many of the basic building-block patents that are most relevant here—issue to research labs doing fundamental science, rather than to companies offering specific product implementations. It is not too surprising that most of those basic research labs are located in universities. Indeed, this may be a pattern with enabling technologies. Darby and Zucker argue that businesses enter into breakthrough technology industries once university scientists publish significant enabling research—what Griliches calls the "invention of methods of inventing."[73]

artifact. A large number of published applications do not list *any* assignee, even though most of those patents will ultimately turn out to be assigned. Allison & Lemley, *supra* note 17, at 2117 (finding that 85.1% of patents are assigned in general). We spot-checked applications from 2001 and found that many of the applications listing no assignee result in issued patents that do list an assignee. Further evidence that this is a data problem and not a trend is that such a finding is true across all the years we studied, even 2001 and 2002. If there were a trend away from university patenting, we would expect to see it reflected in patents that issued in later years. But as Table 2 shows, there is no such trend.

70. *See supra* notes 56-62 and accompanying text.

71. U.S. Patent No. 6,268,041 is owned by Starfire Electronic Development and Marketing; U.S. Patent No. 5,747,161 is owned by NEC; and U.S. Patent No. 5,424,054 is owned by IBM.

72. *See Nanotechnology Updates*, 1 NANOTECHNOLOGY L. & BUS. 130, 131-32 (2004). It is worth noting that these numbers may be skewed because private companies are less likely to announce their patent licenses.

73. Michael R. Darby & Lynne G. Zucker, *Grilichesian Breakthroughs: Inventions of*

Thus, universities may be the drivers of early stage nanotechnology just as they have been with many other enabling technologies. But in nanotechnology, unlike other enabling technologies, the universities are patenting rather than simply publishing their early stage ideas.

Second, unlike the basic, government-sponsored university research of past generations, universities in the modern era are extremely aggressive patenters. This shift was largely precipitated by the Bayh-Dole Act of 1980,[74] which was designed to encourage university technology transfer by permitting universities to patent their federally funded research projects. The results were dramatic. Before 1980, universities worldwide obtained about 250 U.S. patents a year. In 2003, they obtained 3933 patents, an almost sixteen-fold increase.[75] Given this general increase, it is all the more striking that universities hold twelve times as large a proportion of patents in nanotechnology as they do in general. But it may reflect the disproportionate role of academic institutions in early stage technologies more generally, something that we would have seen with prior enabling technologies had universities been involved in patenting when those technologies were in their infancy.

Third, nanotechnology may particularly lend itself to trade secret protection. It is relatively easy to keep many nanotech inventions secret, and even when nanotechnology products are released on the open market, reverse engineering them may be significantly more difficult than in other fields. As a result, companies may choose to forego patent protection in favor of trade secrecy, at least at this early stage. By contrast, universities have no such incentive; the benefit they receive from IP protection of nanotech inventions comes entirely from licensing revenue. Universities may thus be more likely than private companies to patent their inventions. This final explanation, if true, has an interesting side effect—it suggests that the number of nanotechnology patents *understates* the innovation occurring in the field, since much of it is being kept secret.

Methods of Inventing and Firm Entry in Nanotechnology, ANNALES D'ECONOMIE ET STATISTIQUE (forthcoming 2005) (citing Zvi Griliches), *available at* http://www.nber.org/papers/w9825.pdf (last visited Nov. 12, 2005).

74. 35 U.S.C. §§ 200-212 (2005).

75. Wysocki, *supra* note 45 (reporting data from the Association of University Technology Managers). For a discussion of the growth of university patenting and its potential risks, see MOWERY ET AL., *supra* note 41; Katherine J. Strandburg, *Curiosity-Driven Research and University Technology Transfer* (Am. L. & Econ. Assoc. Annual Meetings, Working Paper No. 22, 2005), *available at* http://law.bepress.com/cgi/viewcontent.cgi?article= 1505&context=alea (last visited Oct. 29, 2005).

III. ARE NANOTECH PATENTS GOOD FOR INNOVATION?

A. *The Risks of Overpatenting*

These facts in combination mean that patents will cast a larger shadow over nanotech than they have over any other modern science at a comparable stage of development. Indeed, not since the birth of the airplane a hundred years ago have we seen similar efforts by a range of different inventors to patent basic concepts in advance of a developed market for end products.[76] Some fear that ownership of nanotechnology patents is too fragmented, risking the development of a patent "thicket."[77] Miller offers several examples of nanoscale technologies that have overlapping patents covering the same basic invention, including the carbon nanotube and semiconducting nanocrystals.[78] Others point to similar overlaps involving drug delivery nanoparticles.[79] Further, companies that want to use nanotechnology to produce products may need to use a range of different building-block inventions—for example, using patented atomic force microscopes to detect and align atoms into patented materials that are then manipulated into patented structures used in constructing a patented end product. If each step has one or perhaps several different patents, all owned by different people, the company will need a lot of licenses.

Some will worry that this larger role for patents will interfere with innovation in nanotechnology.[80] While in theory patents spur innovation, they can also interfere with it.[81] Broad patents granted to initial inventors can lock

76. *See supra* note 23. One possible factor reducing the significance of nanotech patents is Doug Lichtman's finding that nanotechnology patents are amended more frequently than those on other types of inventions. Douglas Lichtman, *Rethinking Prosecution History Estoppel*, 71 U. CHI. L. REV. 151 (2004). This may mean that the doctrine of equivalents will play a less significant role in ensuring that those inventions have effective patent scope, a particularly significant limitation in a new and rapidly changing field such as nanotech. *Id.* at 155-56.

77. *See, e.g.*, JOHN C. MILLER ET AL., THE HANDBOOK OF NANOTECHNOLOGY: BUSINESS, POLICY, AND INTELLECTUAL PROPERTY LAW 224 (2005) ("In many different areas of nanotechnology, the intellectual property landscapes are fragmented. A large number of patents held by different entities cover similar inventions and improvements to the same invention."); *id.* at 68 (describing the potential of nanotech building-block patents to stifle downstream innovation and the difficulty of acquiring licenses from many patent holders); Sabety, *supra* note 23, at 262. For a general discussion of the patent thicket, see Carl Shapiro, *Navigating the Patent Thicket: Cross Licenses, Patent Pools, and Standard Setting*, *in* 1 INNOVATION POLICY AND THE ECONOMY 119-22 (Adam B. Jaffe et al. eds., 2001).

78. MILLER ET AL., *supra* note 77, at 69-71. Indeed, Miller goes on to identify no fewer than 306 U.S. patents on nanotubes, including 10 patents claiming the nanotube itself, 20 patents on production methods, and 238 patents on uses of the carbon nanotube. *Id.* at 74.

79. Drew Harris et al., *Strategies for Resolving Patent Disputes over Nanoparticle Drug Delivery Systems*, 1 NANOTECHNOLOGY L. & BUS. 372, 374 (2004).

80. Vaidhyanathan, *supra* note 11, at 2-3.

81. A significant literature discusses the tradeoffs involved in setting the right level of intellectual property protection. This effort at balance is a constant theme in Supreme Court intellectual property cases and the discussions of commentators. *See, e.g.*, Graham v. John

up or retard improvements needed to take a new field from interesting lab results to commercial viability.[82] These building-block patents therefore create

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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."); Mazer v. Stein, 347 U.S. 201, 219 (1954) ("The economic philosophy behind the clause empowering Congress to grant patents and copyrights is the conviction that encouragement of individual effort by personal gain is the best way to advance public welfare . . . ."); *see also* Fogerty v. Fantasy, Inc., 510 U.S. 517, 524 (1994) ("The primary objective of the Copyright Act is to encourage the production of original literary, artistic, and musical expression for the good of the public."); Feist Publ'ns, Inc. v. Rural Tel. Serv. Co., 499 U.S. 340, 349-50 (1991) (stating that the "primary objective of copyright" is to promote public welfare); Stewart v. Abend, 495 U.S. 207, 228 (1990) (noting the Copyright Act's "balance between the artist's right to control the work . . . and the public's need for access"); Bonito Boats, Inc. v. Thunder Craft Boats, Inc., 489 U.S. 141, 167 (1989) (noting the "careful balance between public right and private monopoly to promote certain creative activity"); Sony Corp. of Am. v. Universal City Studios, Inc., 464 U.S. 417, 429 (1984) (stating that the limited monopoly conferred by the Copyright Act "is intended to motivate the creative activity of authors and inventors . . . and to allow the public access to the products of their genius after the limited period of exclusive control has expired"); Twentieth Century Music Corp. v. Aiken, 422 U.S. 151, 156 (1975) (noting that "private motivation must ultimately serve the cause of promoting broad public availability of literature, music, and the other arts"); Goldstein v. California, 412 U.S. 546, 559 (1973) (discussing Congress's ability to provide for the "free and unrestricted distribution of a writing" if "required by the national interest"); Fox Film Corp. v. Doyal, 286 U.S. 123, 127 (1932) ("The sole interest of the United States and the primary object in conferring the monopoly lie in the general benefits derived by the public from the labors of the authors.").

For commentators' discussions, see, for example, 1 PAUL GOLDSTEIN, COPYRIGHT § 1.14, 1:40 (2d ed. Supp. 2005); L. RAY PATTERSON & STANLEY W. LINDBERG, THE NATURE OF COPYRIGHT: A LAW OF USERS' RIGHTS 163-225 (1991); Julie E. Cohen, *Reverse Engineering and the Rise of Electronic Vigilantism: Intellectual Property Implications of "Lock Out" Programs*, 68 S. CAL. L. REV. 1091, 1198 (1995); Matthew J. Conigliaro et al., *Foreseeability in Patent Law*, 16 BERKELEY TECH. L.J. 1045, 1046-47 (2001); Dennis S. Karjala, *Federal Preemption of Shrinkwrap and On-Line Licenses*, 22 U. DAYTON L. REV. 511, 512 (1997); Mark A. Lemley, *Romantic Authorship and the Rhetoric of Property*, 75 TEX. L. REV. 873, 888-89 (1997); Pierre N. Leval & Lewis Liman, *Are Copyrights for Authors or Their Children?*, 39 J. COPYRIGHT SOC'Y 1, 11-12 (1991); Jessica Litman, *The Public Domain*, 39 EMORY L.J. 965, 967-68 (1990); Peter S. Menell, *An Analysis of the Scope of Copyright Protection for Application Programs*, 41 STAN. L. REV. 1045, 1080 (1989); Margaret Jane Radin, *Property Evolving in Cyberspace*, 15 J.L. & COM. 509, 515 (1996). These are only a few of the innumerable citations on this point.

Of course, the operative word here is "balance." Pioneering inventors will emerge only if there are sufficient incentives for them to invent. At the same time, too great a division of rights can impede effective use of technologies. *See* Michael A. Heller & Rebecca S. Eisenberg, *Can Patents Deter Innovation? The Anticommons in Biomedical Research*, 280 SCI. 698, 698 (1998). The fact that the law must also encourage competition to improve such pioneering inventions means that the law must take care to allocate rights between the parties. *See* Craig Allen Nard, *A Theory of Claim Interpretation*, 14 HARV. J.L. & TECH. 1, 36-40 (2000).

82. There are at least three strands to this argument. First, for a variety of reasons, society cannot rely on pioneers to efficiently license to improvers the right to compete with them. *See* Rebecca S. Eisenberg, *Patents and the Progress of Science: Exclusive Rights and Experimental Use*, 56 U. CHI. L. REV. 1017, 1072-73 (1989) ("The risk that the parties will be unable to agree on terms for a license is greatest when subsequent researchers want to use

a greater deadweight loss than improvement patents. On this view, the fact that previous enabling technologies were not generally patented may be thought a happy accident for innovation—or at the very least for follow-on improvers who commercialized particular implementations of these technologies and then patented those implementations. And the problem is not just the existence of broad patents. The dispersion of overlapping patents across too many firms can also create an anticommons or thicket problem, making effective use of the technology difficult, if not impossible.[83] Indeed, the executive director of the NanoBusiness Alliance expressed just such a worry in hearings before Congress, warning that "several early nanotech patents are given such broad coverage, the industry is potentially in real danger of experiencing unnecessary legal slowdowns."[84]

Risks of a patent thicket may be exacerbated by the application of pre-

prior inventions to make further progress in the same field in competition with the patent holder, especially if the research threatens to render the patented invention technologically obsolete."); Mark A. Lemley, *The Economics of Improvement in Intellectual Property Law*, 75 TEX. L. REV. 989, 1048-72 (1997) (offering a variety of reasons why granting exclusive control to pioneers is inefficient); Robert Merges, *Intellectual Property Rights and Bargaining Breakdown: The Case of Blocking Patents*, 62 TENN. L. REV. 75 (1994); Robert P. Merges & Richard R. Nelson, *On the Complex Economics of Patent Scope*, 90 COLUM. L. REV. 839 (1990). Second, positive "spillovers" from innovation that cannot be appropriated by the innovator actually contribute to further innovation. *See, e.g.*, Wesley M. Cohen & David A. Levinthal, *Innovation and Learning: The Two Faces of R&D*, 99 ECON. J. 569 (1989); Zvi Griliches, *The Search for R&D Spillovers*, 94 SCAND. J. ECON. S29 (1992); Richard C. Levin, *Appropriability, R&D Spending, and Technological Performance*, 78 AM. ECON. REV. 424, 427 (1988); Richard Schmalensee, *R&D Cooperation and Competition: Comments and Discussion*, 1990 BROOKINGS PAPERS ON ECON. ACTIVITY (MICROECON.) 194, 195-96 (1990); *cf.* Suzanne Scotchmer, *Standing on the Shoulders of Giants: Cumulative Research and the Patent Law*, 5 J. ECON. PERSP. 29 (1991) (noting difficulties in the optimal allocation of rights between pioneers and improvers). Third, granting strong intellectual property rights encourages rent seeking, which may dissipate the social value of the property rights themselves. *See* Mark A. Lemley, *Property, Intellectual Property, and Free Riding*, 83 TEX. L. REV. 1031, 1056-57 (2005); Jessica D. Litman, *Copyright, Compromise, and Legislative History*, 72 CORNELL L. REV. 857 (1987); Jessica Litman, *Copyright Legislation and Technological Change*, 68 OR. L. REV. 275 (1989); Mark S. Nadel, *How Current Copyright Law Discourages Creative Output: The Overlooked Impact of Marketing*, 19 BERKELEY TECH. L.J. 785 (2005).

83. On the anticommons, see Heller & Eisenberg, *supra* note 81; Michael A. Heller, *The Tragedy of the Anticommons: Property in the Transition from Marx to Markets*, 111 HARV. L. REV. 621, 680-81 (1998); Arti K. Rai, *The Information Revolution Reaches Pharmaceuticals: Balancing Innovation Incentives, Cost, and Access in the Post-Genomics Era*, 2001 U. ILL. L. REV. 173, 192-94. On the closely related concept of the patent thicket, see James Bessen, *Patent Thickets: Strategic Patenting of Complex Technologies* (Research on Innovation Working Paper 2003), *available at* http://www.researchoninnovation.org/thicket.pdf.

84. *Hearing on Nanotechnology: Hearing Before the Subcomm. on Science, Technology, and Space of the S. Comm. on Commerce, Science, and Transportation*, 107th Cong. (2002) (statement of Mark Modzelewski, Executive Director, NanoBusiness Alliance), *available at* http://commerce.senate.gov/hearings/testimony.cfm?id=845&wit_id=2323.

nanotechnology patents to nanotech inventions. For example, a last-generation patent on an invention in microprocessors might call for a "sub-micron gate." Such a claim would be literally infringed by a gate of 100 nm, even though the design and behavior of the materials in the nano-sized gate might be fundamentally different than those of a gate of 950 nm. If pre-nanotechnology patents are interpreted to cover their nanotech counterparts, it would multiply significantly the number of patents with which nanotech companies have to deal. Arguably, those patents should not apply, for the very reason that there is something unique about the nanoscale that affects the behavior of materials in ways that pre-nanotech inventors did not contemplate. As a result, some have suggested that nanotechnologies should escape infringing those older patents under the reverse doctrine of equivalents,[85] though recent case law is not encouraging for application of the doctrine.[86] A similar issue arose in electronics during the transition from analog to digital technology; courts there had to consider whether technology from an older generation could apply to new inventions accomplishing similar goals but in different ways. The results from that experiment were mixed.[87] The specter of pre-nanotech patents piling onto the large number of nanotech patents may make the patent thicket loom large in the minds of innovators in this industry.

It is too early to tell whether these concerns will come to pass. The early airline industry was locked in debilitating patent disputes for a decade, until the government stepped in during World War I and required the parties to cross-license their patents.[88] In radio, which Ted Sabety suggests is a better analogy to nanotechnology, hundreds of patents sprung up and produced substantial litigation and patent pooling. Sabety concludes that they did not significantly impede downstream innovation,[89] but that result may simply be a function of the government-sponsored creation of RCA as a patent pool.[90]

85. Andrew Wasson, *Protecting the Next Small Thing: Nanotechnology and the Reverse Doctrine of Equivalents*, 2004 DUKE L. & TECH. REV. 10. For a general discussion of the doctrine, see Merges, *supra* note 82.

86. *Tate Access Floors, Inc. v. Interface Architectural Resources, Inc.*, 279 F.3d 1357 (Fed. Cir. 2002), purported to abolish the doctrine or at least to say it was coextensive with the reach of 35 U.S.C. § 112, ¶ 6 (2005). But the Federal Circuit reaffirmed the continued vitality of the doctrine not long after in *Amgen, Inc. v. Hoechst Marion Roussel, Inc.*, 314 F.3d 1313 (Fed. Cir. 2003).

87. For a discussion, see Cohen & Lemley, *supra* note 30, at 45-47, 54-56.

88. *See, e.g.*, Bittlingmeyer, *supra* note 23; Robert P. Merges, *Contracting into Liability Rules: Intellectual Property Rights and Collective Rights Organizations*, 84 CAL. L. REV. 1293, 1356-57 (1996).

89. Sabety, *supra* note 23, at 275-76.

90. The third example of basic building-block patents—xerography—teaches a different lesson. While xerography is an example of patents on basic building-block technologies in what is at least arguably an enabling industry, the fact that the patents were owned by a single entity helped avoid the patent thicket problems that nanotech faces. While central control over an enabling technology prevents open competition to exploit that breakthrough, it does at least have the virtue of permitting one company to exploit the

But the fact that patenting of basic technologies led to problems in the past doesn't necessarily mean it will in the future. Recent developments in genomics suggest that it may be possible for patent owners to act collectively to open fundamental resources to individual exploitation, at least where the owners' incentives are largely symmetric.[91] It is not clear whether a similar arrangement is possible in nanotech, given the somewhat different interests of firms applying nanoscale inventions in different engineering fields. If it isn't, downstream innovation may be either rendered illegal or, at best, constrained within official channels pre-licensed by patentees. Scholars have worried in other contexts that such pioneer control over follow-on innovation may not be optimal.[92] And while universities could at one time rely with some confidence on their effective immunity from suit for engaging in basic experimentation, that is no longer true.[93]

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technology, while a patent thicket risks permitting no one to do so.

91. *See, e.g.*, Sara Boettiger & Dan L. Burk, *Open Source Patenting*, 1 J. INT'L BIOTECHNOLOGY L. 221, 222-24 (2004); Robert P. Merges, *A New Dynamism in the Public Domain*, 71 U. CHI. L. REV. 183 (2004); Arti K. Rai, *"Open and Collaborative" Research: A New Model for Biomedicine*, *in* INTELLECTUAL PROPERTY RIGHTS IN FRONTIER INDUSTRIES: SOFTWARE AND BIOTECHNOLOGY 131 (Robert W. Hahn ed., 2005) (all discussing open-source genomics). The computer and telecommunications industries have somewhat similar rules mediated through the mechanism of standard-setting organizations. *See* Lemley, *supra* note 35, at 1896-97. And portions of the software industry achieve this result through the mechanism of open-source licensing, at least where copyright rather than patent rights are concerned. *See* Yochai Benkler, *Coase's Penguin, or, Linux and the Nature of the Firm*, 112 YALE L.J. 369 (2002); David McGowan, *Legal Implications of Open-Source Software*, 2001 U. ILL. L. REV. 241; Greg R. Vetter, *The Collaborative Integrity of Open Source Software*, 2004 UTAH L. REV. 563.

92. *See* Kenneth J. Arrow, *Economic Welfare and the Allocation of Resources for Invention*, *in* THE RATE AND DIRECTION OF INVENTIVE ACTIVITY 609, 620 (Nat'l Bureau of Econ. Research ed., 1962), *reprinted in* 5 KENNETH J. ARROW, COLLECTED PAPERS OF KENNETH J. ARROW: PRODUCTION AND CAPITAL 104, 116 (1985) (concluding that "preinvention monopoly power acts as a strong disincentive to further innovation"); *see also* MORTON I. KAMIEN & NANCY L. SCHWARTZ, MARKET STRUCTURE AND INNOVATION (1982); (discussing various theories of the effects of economic structures on the rate and form of innovation); F.M. SCHERER & DAVID ROSS, INDUSTRIAL MARKET STRUCTURE AND ECONOMIC PERFORMANCE 660 (3d ed. 1990) (criticizing Schumpeter's "less cautious" followers for advocating monopoly to promote innovation). In the specific context of intellectual property, the canonical argument from both theory and empirical evidence is found in Merges & Nelson, *supra* note 28. *See also* Kenneth W. Dam, *The Economic Underpinnings of Patent Law*, 23 J. LEGAL STUD. 247, 252 (1994) (noting that in the computer industry, for example, companies coordinate improvements by broad cross-licensing because of "the pace of research and development and the market interdependencies between inventions"). For discussions of particular industries in which competition appears to spur innovation, see, for example, Mark A. Lemley & Lawrence Lessig, *The End of End-to-End: Preserving the Architecture of the Internet in the Broadband Era*, 48 UCLA L. REV. 925, 960-62 (2001) (the Internet); Arti Kaur Rai, *Evolving Scientific Norms and Intellectual Property Rights: A Reply to Kieff*, 95 NW. U. L. REV. 707, 709-11 (2001) (biotechnology); Howard A. Shelanski, *Competition and Deployment of New Technology in U.S. Telecommunications*, 2000 U. CHI. LEGAL F. 85, 85 (telecommunications).

93. *See* Madey v. Duke Univ., 307 F.3d 1351 (Fed. Cir. 2002) (effectively eliminating

Another consideration is practical—nanotechnology patents may be difficult to enforce because it is hard to detect infringement.[94] There are, to date, relatively few products that use nanotech inventions; much of whatever infringement of nanotechnology patents occurs today is confined to research laboratories. It is hard to tell from the outside whether a lab is using a particular invention, and it is therefore hard to establish the legal basis for an infringement action. As a result, it is possible that the nanotechnology industry will avoid a patent thicket at the research stage in much the way biotechnology seems to have done: not by limiting the scope or issuance of patents, but by simply ignoring them.[95] Individual patents might be invalid as well, as nearly half of all litigated patents are.[96] Ignoring patents will be harder once nanotechnology products are actually sold on the market, of course. But researchers might be able to avoid many infringement suits during the period when they are still experimenting with building-block technologies.

B. *Licensing as a Solution to Overpatenting*

In thinking about the policy implications of nanotechnology patents, we should begin by asking whether and how companies and the law can harness the incentives provided by the patent system while minimizing the risks that strong patents pose for downstream innovation. One way businesses can respond to these challenges is by open licensing—that is, licensing a technology widely. Open licensing of basic building-block patents is desirable in enabling technologies, because there may be numerous different uses for the technology, and a single firm with central control over product development is unlikely to foresee or be able to exploit all of those uses.

Whether open licensing will happen depends critically on the distribution of core patents among firms and on the markets in which those firms participate. If core patents are distributed roughly evenly among firms participating in a market driven by nanotechnology, those firms will have a strong incentive to enter into cross-licenses, since their interests are symmetrical: they need their competitors' patents just as much as the

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the common law experimental use defense).

94. *See* MILLER ET AL., *supra* note 77, at 226 ("At this stage, it is difficult to detect infringement of nanotechnology patents.").

95. *See* John P. Walsh et al., *Research Tool Patenting and Licensing and Biomedical Innovation*, *in* PATENTS IN THE KNOWLEDGE-BASED ECONOMY 285, 285-86, 331-32 (Wesley M. Cohen & Stephen A. Merrill eds., 2000) (investigating the impact of research tool patents in biotechnology and finding that they did not interfere with product introduction, in significant part because researchers simply ignored them); John P. Walsh et al., *Working Through the Patent Problem*, 299 SCI. 1021 (2003).

96. John R. Allison & Mark A. Lemley, *Empirical Evidence on the Validity of Litigated Patents*, 26 AIPLA Q.J. 185, 205 (1998) (finding a forty-six percent invalidity rate).

competitors need their patents.[97] Indeed, there are some early examples of nanotech patents being cross-licensed within an industry.[98] Still, Miller is skeptical that semiconductor-style cross-licenses will work in nanotechnology because of the disparity in size and business model among the stakeholders.[99] In short, he doubts whether the interests of nanotechnology patent owners are in fact symmetrical.

If patents are distributed asymmetrically, but are concentrated in established firms in different industries rather than nanotech-specific tool firms,[100] it is reasonable to expect that those firms holding core patents will use them to exclude competition in their particular industry.[101] But there is no reason to believe such a firm will have any incentive to exclude competition in other industries. For example, if a large biotech company holds a critical nanotech building-block patent, it will likely seek to exclude competing biotech firms from using the patented invention, but it will have no interest in precluding semiconductor firms from using the same invention. Rather, it is reasonable to expect the patent owner to license the invention outside its industry for a royalty.[102] A more troubling possibility is that the biotech firm in this example will grant an exclusive license to one semiconductor firm rather than grant a series of nonexclusive licenses. Exclusive licenses tend to produce a higher royalty rate, and companies may therefore have an incentive to prefer them. But their effect may be to shut competitors out of a market, or at least out of the use of a particular technology.

Finally, if the market is vertically segmented, downstream firms will need to pay money in order to license patents from the upstream nanotech patent owners. Nanotechnology-specific firms that don't make downstream products themselves will likely be more interested in licensing in each industry, though they too may have an incentive to prefer exclusive rather than nonexclusive licensing in each field. But if they are not making products themselves, a

97. This is what has happened in the semiconductor industry. *See* Bronwyn H. Hall & Rosemarie Ham Ziedonis, *The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry, 1979-1995*, 32 RAND J. ECON. 101 (2001). It is no accident that semiconductor patents are far less likely to be litigated than patents in any other industry. Allison et al., *supra* note 66, at 472-73 & tbl.3.

98. *See* Harris et al., *supra* note 79, at 383-87 (discussing the BioCrystal-Crystalplex cross-license).

99. MILLER ET AL., *supra* note 77, at 76.

100. The Ratners predict this outcome. RATNER & RATNER, *supra* note 1, at 146.

101. Harris et al. document three examples of nanotech patent litigation to date. Harris et al., *supra* note 79, at 387-89 & nn.15-16 (discussing Caliper Technologies's suit against Molecular Devices, Ultratech's suit against Tamarack Scientific, and Veeco Instruments's suit against Asylum Research).

102. It is also possible to imagine a sort of cross-licensing across industries, if the biotech firm has patents the semiconductor firm needs and vice versa. The larger the corporations and their patent portfolios, the more likely such a tradeoff is. But it will be much less common than the more straightforward case of cross-licensing by competitors.

situation that seems likely in the biotech and semiconductor markets at least, they will not be interested in trading patents. Instead, they will want money to license their patents.

The demand for royalties by patent owners who are not in a symmetric position with other patent owners isn't itself a problem if there are relatively few such patents. But in a patent thicket, the number of competing claimants for royalties will swamp those firms that want to operate in the industry. The need to acquire rights from many different players creates what economists call the "double marginalization" or holdup problem.[103] Once two or more patent owners hold rights each of which is necessary to produce a product, we can no longer assume that efficient licensing will occur. We have seen something similar with the proliferation of patent "trolls" in the telecommunications and computer industries and the associated bargaining breakdown.

If patent owners are not inclined to open licensing, firms need to find ways to produce without infringing those patents. Designing around a patent may be possible, but it will prove harder in nanotechnology than in other fields if, as I suggest, nanotech patents are broader and more basic than those in other fields. One way for companies making downstream products to avoid infringing upstream patents is to purchase one or more upstream nanotechnology research firms that own such patents. Such vertical integration obviously avoids infringement of the purchased firm's patents. But it may also put the downstream firm in a better bargaining position vis-à-vis other patent owners, since that firm will now have something to trade. And by concentrating patent rights in a smaller group of companies, vertical integration reduces the risk of holdup. Whether this trading will occur depends largely on how other firms behave. If other firms also vertically integrate, the vertically integrated firms will be in a symmetrical relationship and will have similar incentives to cross-license. If only one firm integrates vertically, it will still have to deal with other upstream patent firms that seek license revenue. Vertical integration also implicates the antitrust laws, though modern courts generally treat it leniently,[104] and the ability of firms to reduce innovation risks by means of vertical merger provides an additional reason for antitrust courts to continue this deference.

The significant role played by university patents might at first blush be thought to ameliorate many of the risks identified above. Universities, after all,

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103. The double-marginalization theorem shows that it is inefficient to grant two monopolies in complementary goods to two different entities because each entity will price its piece without regard to the efficient pricing of the whole, resulting in an inefficiently high price. For a technical proof of this theorem, see Carl Shapiro, *Setting Compatibility Standards: Cooperation or Collusion?*, *in* EXPANDING THE BOUNDARIES OF INTELLECTUAL PROPERTY 81, 97-101 (Rochelle Cooper Dreyfuss et al. eds., 2001).

104. *See* IVA PHILLIP E. AREEDA, HERBERT HOVENKAMP & JOHN L. SOLOW, ANTITRUST LAW: AN ANALYSIS OF ANTITRUST PRINCIPLES AND THEIR APPLICATION ¶ 1000a (rev. ed. 1998).

are not competing with private firms to make products and so lack incentives to prevent their competitors from using their inventions. Universities have traditionally played an important role in early stage technology transfer even without patents.[105] Further, precisely because universities do early stage research, they patent inventions that are far from commercialization; they may therefore actually speed the entry of some inventions into the public domain by obtaining patents that expire earlier.[106] This may be particularly significant in nanotechnology, given the slow pace of commercialization to date.

In fact, however, there may be reason to worry that university patents will be more restrictive of nanotechnology than industry patents. First, precisely because a university is not a market participant, it is not in a symmetrical relationship with other patentees.[107] Nor can it vertically integrate by merging with a downstream products firm. Some prior evidence has shown that patentees in such an asymmetric position are more likely to enforce their rights, because they are interested only in maximizing their licensing revenue rather than in cross-licensing.[108] In the semiconductor industry, for example, the established players rarely sue each other,[109] and most lawsuits are filed by outsiders who are not making products in the industry. And, indeed, universities have proven themselves adept at licensing patents for money. Collectively, they take in over $1 billion a year in patent licensing revenue.[110]

Second, universities have generally maximized licensing revenues by granting exclusive rather than nonexclusive licenses. For most inventions this makes sense as an economic matter; to the extent any patent confers power over price, the private value of that power will be maximized by keeping control within a single firm. Accordingly, the royalty rates for exclusive

105. *See* MOWERY ET AL., *supra* note 41, at 2 ("[I]n many cases patenting of an invention by a university is not necessary to support the transfer and commercialization of an invention."); UNIVERSITY ENTREPRENEURSHIP AND TECHNOLOGY TRANSFER: PROCESS, DESIGN, AND INTELLECTUAL PROPERTY (Gary Libecap ed., 2004).

106. *See* John F. Duffy, *Rethinking the Prospect Theory of Patents*, 71 U. CHI. L. REV. 439, 444 (2004). I am indebted to David Jaffer and Greg Mandel for this point.

107. To be sure, this is not entirely true. To the extent corporations own basic research tool patents, they could enforce those patents against universities engaged in nanotechnology research. The Federal Circuit has made it clear that universities enjoy no special exemption from patent liability stemming from their research. *See* Madey v. Duke Univ., 307 F.3d 1351, 1362-63 (Fed. Cir. 2002) (effectively eliminating the common law experimental use defense). But this is likely to be an exceptional case. By and large, universities will be more likely to hold building-block patents, whereas businesses will be more likely to hold implementation patents. Those implementation patents will not generally be enforceable against universities.

108. *See* Allison et al., *supra* note 66, at 468-70.

109. *Id.* at 472-73 & tbl.3 (noting that the rate of semiconductor litigation is roughly only one-third the rate in other industries).

110. Jerry G. Thursby & Marie C. Thursby, *University Licensing and the Bayh-Dole Act*, 301 SCI. 1052, 1052 (2003); *see also The Big Ten: Universities that Made the Most Licensing Dollars Last Year*, IP L. & BUS., Jan. 5, 2005, at 14.

licenses are significantly higher than the rates for nonexclusive licenses. But for certain basic inventions—specifically, those that enable broad or unpredictable new directions in research—exclusive licensing has significant social and perhaps even private costs, because it limits competition in the exploitation of those building blocks and so interferes with the resulting follow-on innovation.[111] This is a particular risk in nanotechnology, where a basic invention may have applications in a number of different industries that a single private firm cannot exploit efficiently.

Ideally, universities will recognize that enabling technologies are more valuable not just to society but even to their owners when many firms compete to exploit and improve them. For that class of inventions, therefore, the university can maximize its revenue by licensing the patent nonexclusively or, at a bare minimum, by limiting exclusivity to one particular field of endeavor. The Axel and Cohen-Boyer licenses from biotechnology are good examples of the wisdom of this approach. But nonexclusive licensing of nanotechnology patents requires a certain amount of swimming upstream on the part of licensing professionals,[112] as well as an ability to distinguish basic building-block inventions from other inventions for which an exclusive license is appropriate. The (admittedly meager) record so far is not promising. Of fifteen publicly announced nanotechnology license agreements in 2003, all but two or three were exclusive,[113] and all nine of the licenses granted by universities were exclusive, though one was exclusive only with respect to biological applications.[114] The ETC Group reports that between 2003 and 2005, universities publicly announced twenty nanotechnology licenses, of which at least nineteen and perhaps all twenty were exclusive.[115] If universities do continue to grant exclusive licenses, it will matter greatly whether those licenses are to large players with incentives to cross-license the patents or to small upstream players who will in turn seek royalties.

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111. This depends on whether improvement on a basic invention is better centrally coordinated or left to a competitive market. I have argued in detail elsewhere that it is best left to a competitive market. *See* Mark A. Lemley, *The Economics of Improvement in Intellectual Property Law*, 75 TEX. L. REV. 989 (1997).

112. A study of university technology-transfer offices in 2000 found that half of their licenses were exclusive, but that ninety percent of their licenses to start-ups were exclusive. *See* ANN MONOTTI & SAM RICKETSON, UNIVERSITIES AND INTELLECTUAL PROPERTY: OWNERSHIP AND EXPLOITATION 447 (2003). Technology-transfer officers claim that exclusive licenses are essential to attract interest from licensees. *Id.* at 448.

113. Information was unavailable for one commercial license.

114. Calculations from *Nanotechnology Updates*, *supra* note 72, at 131-32. Put another way, between 89% and 100% of the university licenses were exclusive, compared with only 50% to 67% of the corporate licenses. The small sample size prevents drawing any definitive conclusions from these differences, however.

115. ETC GROUP, NANOTECH'S "SECOND NATURE" PATENTS: IMPLICATIONS FOR THE GLOBAL SOUTH 14 (2005), http://www.etcgroup.org/documents/Com8788SpecialPNanoMar-Jun05ENG.pdf.

C. *Legal Solutions to Overpatenting*

If we conclude that the proliferation of strong and broad nanotechnology patents will inhibit innovation, how might the law respond? One possibility would be to limit the strength of nanotechnology patents, perhaps by imposing a strict utility requirement that shifts patents away from upstream tools and raw materials towards downstream implementations. The law does something similar in chemistry and biotechnology by imposing a utility requirement absent in the rest of patent law.[116] If there is a significant risk that nanotechnology innovation will be retarded by broad upstream patents, we can replicate by law the result we got by accident in the biotech, software, hardware, and Internet industries—freedom to use basic tools and processes with patents only on downstream implementations.[117]

A second possibility along the same lines is to restrict the ability of universities and other owners of basic building-block patents to impose exclusive licenses that restrict downstream innovation. Most of this building-block technology is publicly funded, and the government has the power under the Bayh-Dole Act to compel licensing of that technology on reasonable terms.[118] It has never used this power,[119] but some scholars have suggested that it may be appropriate to do so to ensure that the basic tools of nanotechnology are not locked up in exclusive licenses.[120] Certainly the lesson of the Axel and Cohen-Boyer patents is that nonexclusive licensing by universities helped jump-start the biotechnology industry and likely made more money for the universities involved than an exclusive license to a start-up would have.

While these options could help solve thicket problems that might develop, it does not seem appropriate at this early stage to restrict upstream nanotech patenting. Nanotech inventions will require substantial investment that will not be recouped for a long time, if ever. Development of basic nanotech building blocks such as carbon nanotubes is itself a complex and uncertain process.

116. *See, e.g.*, *In re* Kirk, 376 F.2d 936, 961 (C.C.P.A. 1967) (Rich, J., dissenting) (arguing that *Brenner*'s utility requirement would never be "indulged in with respect to other scientific 'tools' of a mechanical or optical or electronic sort"); Burk & Lemley, *supra* note 25, at 1646. Forman endorses the use of utility as a technology-specific policy lever, though he believes the doctrine as applied to biotechnology is currently too powerful. Julian David Forman, *A Timing Perspective on the Utility Requirement in Biotechnology Patent Applications*, 12 ALB. L.J. SCI. & TECH. 647, 650 (2002).

117. For an argument against such an approach, see David S. Almeling, Note, *Patenting Nanotechnology: Problems with the Utility Requirement*, 2004 STAN. TECH. L. REV. N1, ¶¶ 42-48, http://stlr.stanford.edu/STLR/Articles/index.htm.

118. 35 U.S.C. § 203(a) (2005).

119. For a discussion of one famous petition asking the government to do so, see Barbara M. McGarey & Annette C. Levey, *Patents, Products, and Public Health: An Analysis of the CellPro March-in Petition*, 14 BERKELEY TECH. L.J. 1095 (1999).

120. *See* Sabety, *supra* note 23, at 19-20; *cf.* Arti K. Rai & Rebecca S. Eisenberg, *Bayh-Dole Reform and the Progress of Biomedicine*, 66 LAW & CONTEMP. PROBS. 289, 312-14 (2003) (discussing similar measures that might be taken in biomedicine).

Turning those building blocks into usable products will take significant further research, and the commercial applications in many cases will not be apparent for some time. Both of these characteristics—the large investment in research and development required to produce *inventions* and the long and uncertain process of *innovating*[121]—suggest that nanotech patents, like pharmaceutical patents, should be relatively broad.[122] Patents provide a needed incentive for research and development into nanotech by established companies moving into the field and for venture capital investment in start-up nanotech ventures, though their importance in funding university- and government-backed projects is less clear.[123]

Restricting nanotech patents is also premature because we have not yet had an opportunity to see how significant the patents will turn out to be, how they will be licensed, and how industry participants will react. Biotechnology provides a somewhat encouraging example. While many of the basic building blocks entered the public domain, others were patented, but those patents were licensed by universities on nonexclusive terms. Perhaps the same thing will happen in nanotechnology. On the other hand, the costs of solving the problem after the fact may be significantly greater than the costs of preventing it in the first instance. If we wait and it turns out that broad nanotech patents are holding up innovation, courts and Congress will have to consider whether there are policy levers that can prevent this result without interfering with the incentives that patents grant to pioneers. One possibility at this later stage is a rule that limits injunctive relief in patent cases to patent owners who are also market participants.[124] Such a rule would permit patent owners to recoup a reasonable

121. I follow Schumpeter here in distinguishing between the act of inventing—coming up with a new idea—and innovating—turning that idea into a marketable product. *See* DIRECT PROTECTION OF INNOVATION 35-38 (William Kingston ed., 1987); RICHARD R. NELSON & SIDNEY G. WINTER, AN EVOLUTIONARY THEORY OF ECONOMIC CHANGE 263 (1982) (distinguishing the invention of a product from innovation, a broader process of research, development, testing, and commercialization of that product, and attributing that distinction to Schumpeter).

122. *See, e.g.*, Burk & Lemley, *supra* note 25, at 1684-87 (arguing for strong patent protection of pharmaceuticals).

123. Some scholars have suggested that patents issued to these latter groups under the Bayh-Dole Act might be limited in significant ways. *See* Rochelle Dreyfuss, *Protecting the Public Domain of Science: Has the Time for an Experimental Use Defense Arrived?*, 46 ARIZ. L. REV. 457, 468-72 (2004); Rai & Eisenberg, *supra* note 120.

124. *See* Julie S. Turner, Comment, *The Nonmanufacturing Patent Owner: Toward a Theory of Efficient Infringement*, 86 CAL. L. REV. 179 (1998); *see also* Michelle Armond, Comment, *Introducing the Defense of Independent Invention to Motions for Preliminary Injunctions in Patent Infringement Lawsuits*, 91 CAL. L. REV. 117 (2003) (proposing a different solution directed at the same problem of enforcement by nonmanufacturing patent owners). There are issues with the implementation of such a rule that would have to be addressed, such as the extent to which licensing a patent qualifies as participating in a market and whether to exempt patents on research tools that generate primarily data rather than products. In any event, the Federal Circuit has flatly rejected such a rule. MercExchange LLC v. eBay, Inc., 401 F.3d 1323 (Fed. Cir. 2005).

royalty but not to hold up innovation by actual market participants. And importantly, such an approach could be implemented after the fact, permitting us not to jump to the conclusion that we need new rules for this emerging industry.

One thing that the law could do now that would ameliorate the risk of a nanotechnology patent thicket is to change some of the rules that encourage opportunistic holdup, particularly by patent owners in industries with products that combine many different technologies. The ability of patent owners to file an unlimited number of continuations,[125] to keep certain patent applications secret,[126] to seek treble damages even against defendants who independently developed the invention,[127] and to threaten injunctions against whole products even if a small component is found to infringe[128] has created a thriving economy of patent "trolls." These patent trolls game the system in an effort to capture not only the value of their inventions, but the value of complementary assets and irreversible investments made by defendants as well. Changing that culture—seeking to ensure that patentees are entitled to recover for the value of their invention but not to hold up developers of complex products for a disproportionate share of the product's value—would also help the nascent nanotechnology industry avoid the problems that have beset semiconductors, the Internet, and various other information technology industries.

CONCLUSION

Nanotechnology patents bear watching. They have characteristics that may well make them fundamentally different than patents in any other industry in the last eighty years. How the market responds to these characteristics will determine whether and how the law must step in and tailor the rules of patent law to the needs of this nascent industry. It will also give us broader insight into the role of patents in enabling technologies. It is premature to do much more than watch, however. We should fix the problems that already appear in the patent system, but the fixes are general ones, not solutions specific to nanotechnology.

Nanotechnology is a natural experiment that can teach us whether we have learned anything since the days of the Wright brothers about how to license and enforce patents without restricting innovation, or whether the absence of early patent protection for the enabling technologies of the last century was merely a series of fortunate events.[129]

125. *See, e.g.*, Lemley & Moore, *supra* note 55, at 66-70.

126. 35 U.S.C. § 122(b)(1)(B) (2005).

127. *See, e.g.*, Mark A. Lemley & Ragesh K. Tangri, *Ending Patent Law's Willfulness Game*, 18 BERKELEY TECH. L.J. 1085 (2003).

128. *See, e.g.*, *eBay, Inc*., 401 F.3d at 1329-30.

129. With apologies to Lemony Snicket.