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# NANOSCALE

## ISSUES AND PERSPECTIVES FOR THE NANO CENTURY

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“Now nanotechnology had made nearly everything possible, and so the cultural role in deciding what should be done with it had become far more important than imagining what could be done with it.”

—Neal Stephenson, *The Diamond Age or a Young Lady's Primer* (1995)

“Each new power won *by* man is a power *over* man as well. Each advance leaves him weaker as well as stronger. In every victory, besides the general who triumphs, he is a prisoner who follows the triumphal car . . . *Human* nature will be the last part of Nature to surrender to Man. The battle will then be won. We shall have “taken the thread out of the hands of Clotho” and be free henceforth to make of our species whatever we wish it to be. The battle will indeed be won. But who, precisely, will have won it?”

—C. S. Lewis, *The Abolition of Man* (1943)

“[T]he discoverer of an art is not the best judge of the good or harm which will accrue to those who practice it.”

—Plato, *Phaedrus* (c. 370 BC)

“Science Finds, Industry Applies, Man Conforms”

—Motto of Chicago World's Fair, 1933–34 (Century of Progress Exposition)

# Patenting Trends in Nanotechnology<sup>1</sup>

JESSICA K. FENDER

## INTRODUCTION

The United States is experiencing tremendous growth in nanotechnology research. The National Science Foundation (NSF) has predicted that nanotechnology-related goods and services will reach \$1 trillion by 2015, exceeding the combined economic impact of the telecommunications and information technology industries during the technology boom of the 1990s.<sup>2,3</sup> One of the ways to measure this growth is to track nanotechnology patenting activity. As nanotechnology inventions move from theory to commercialization, the number of nanotechnology patents granted by the U.S. Patent and Trademark Office (USPTO) is expected to increase dramatically. Today, nanotechnology patents account for approximately 0.7% of all patents issued by the USPTO.<sup>4</sup> There are more nanotechnology patents now than there were biotechnology patents at a similar stage in the biotechnology field's development.<sup>5</sup> The number of nanotechnology-related scientific and technological articles is also significantly higher than the number of biotechnology-related articles at a comparable time, indicating nanotechnology patents may soon overtake biotechnology patents in number.<sup>6</sup>

<sup>1</sup>This material is based upon work supported by the National Science Foundation (NSF) under grant SES-0508321 and the Office of Science, U.S. Department of Energy (DOE) under Award Number DE-FG02-06ER64276.

<sup>2</sup>R. Bawa, "Nanotechnology Patenting in the US," 1 *Nanotechnology Law & Business* 31–50, 37 (2004).

<sup>3</sup>M. C. Roco, "The US National Nanotechnology Initiative After 3 Years (2001–2003)," 6 *Journal of Nanoparticle Research* 1–10, 4 (2004).

<sup>4</sup>L. G. Zucker and M. R. Darby, "Socio-Economic Impact of Nanoscale Science: Initial Results and Nanobank," *NBER Working Paper Series* 11181, 1–31, 9 (2005).

<sup>5</sup>L. G. Zucker and M. R. Darby, "Socio-Economic Impact of Nanoscale Science: Initial Results and Nanobank," *NBER Working Paper Series* 11181, 1–31, 9 (2005).

<sup>6</sup>M. A. Lemley, "Patenting Nanotechnology," 58 *Stanford Law Review* 601–630, 605 (2005).

This chapter addresses the issues and trends in nanotechnology patents in the United States by comparing studies that identified a set of nanotechnology patents and analyzed them.<sup>7</sup> The studies illustrate how nanotechnology patenting has changed and grown over the last three decades. They provide key information, such as which entities are obtaining the most patents and which technological fields are experiencing the largest impact from nanotechnology research. The studies report results from as early as 1976, with some data being collected as recently as 2005. The researchers range from corporate research groups to law firms and academics. Methodologies vary widely; for example, some researchers identified nanotechnology patents by searching for nanotechnology-related terms in the patent title, whereas others searched for a given term throughout the entire body of the patent. The data reported in each study varies as a result of these methodological differences, and the methodologies are, therefore, presented in conjunction with the results to put them into context. The studies are referred to by the primary author's last name, or the group name when applicable.

## RESULTS

### Nanotechnology Patents on the Rise

Each study reported on the number of nanotechnology patents issued by the USPTO. The USPTO website allows one to search published patent applications from March 2001, whereas complete data on issued patents is available from 1976.<sup>8</sup> The number of patents reported by each study varies depending on three factors: which date range the author searched, which search terms the author used, and which part of the patent the author analyzed.<sup>9</sup> These parameters provide an explanation for most observed variances between the reported results.

In general, the study authors compiled their results by searching issued patents or published patent applications that contained terms relating to nanotechnology. The two studies that searched the entirety of the issued patent language (e.g., as

opposed to only patent titles or abstracts) reported the highest number of nanotechnology patents.

The Tullis study reported the highest numbers overall, with 96,312 patents that purportedly relate to nanotechnology. These results are the product of two factors. First, Tullis did not provide a range of dates, but referenced the USPTO website, indicating that he likely searched issued patents from 1976 until the day he ran the search on September 2, 2005.<sup>10</sup> Second, he did not filter his results, and he used the broad prefix "nano" as his only search term. Most of the other studies either chose specific search terms (e.g., quantum dot) or excluded measurement terms when they searched for the term "nano." Measurement terms may appear in patents that do not address nanotechnology; for example, the term "nanometer" could appear in any patent referencing the electromagnetic spectrum, such as a patent for an incandescent light bulb.<sup>11</sup>

This issue comes into focus upon repeating Tullis' search. One patent that comes up as a "hit" is a patent for a cleaning agent that uses the chemical compound sodium nitrate ( $\text{NaNO}_3$ , which the computer search engine recognized as containing the term nano).<sup>12</sup> The patent makes no claim to any nanotechnology-related invention. On the other hand, excluding measurement terms may also lead to artificially low numbers, as patents claiming nanotechnology more than likely include a term, such as "nanometer." U.S. Patent No. 7,005,669 provides just such an example—the patent claims quantum dots, nanocomposite materials of quantum dots, and devices using quantum dots, and therefore clearly contains nanotechnology-related inventions. However, the patent also contains the term nanometer, and, therefore, would have been excluded if all measurement terms were culled from the search results.

The Huang et al.,<sup>13</sup> study largely avoided these problems by constructing a specific set of search terms to identify nanotechnology-related patents. The Huang group performed two studies. The first study, published in 2003, examined nanotechnology patents from January 1976 to December 2002, while the second study updated and refined those data and collected new data from 2003.<sup>14,15</sup> It is

<sup>7</sup>There are nine studies discussed in this chapter. The studies were chosen for comparison because the researchers disclosed something about their search methodologies in addition to reporting on the number of nanotechnology patents they identified. Methodology is key to meaningful interpretation of each study's data.

<sup>8</sup>Pre-grant patent applications are available as of 2001, when the American Inventors Protection Act (AIPA) went into effect. *American Inventors Protection Act of 1999*, Pub. L. No. 106-113, § 1000(a)(9), 113 Stat. 1536 (1999). Patent applications were not routinely published prior to 2001, but now applications are generally published 18 months after their filing date. Issued patents are available in full text after 1976, whereas patents issued prior to 1976 are searchable only by patent number, issue date, and current U.S. classifications. USPTO, "Patent Full-Text and Full-Page Image Databases." Available at <http://www.uspto.gov/patft/index.html>, last viewed June 15, 2006. The applicant can request the application remain secret but only if the applicant has not filed for the same invention in a foreign country subject to the Patent Cooperation Treaty.

<sup>9</sup>For those unfamiliar with patents, a patent consists of various distinct parts. These include: a title; an abstract, which is a brief summary of the invention; the specification, which provides background information on the invention, as well as a detailed description of the new invention; and the claims, which define the boundaries of the patent applicant's legal right to exclude others from practicing the invention.

<sup>10</sup>T. K. Tullis, Comment, "Application of the Government License Defense to Federally Funded Nanotechnology Research: The Case for a Limited Patent Compulsory Licensing Regime," 53 *UCLA Law Review* 279, 282, 282 n.11 (2005).

<sup>11</sup>See, e.g., *Improving Incandescent Bulb Efficiency*, U.S. Patent No. 4,196,368 (filed Sept. 7, 1977).

<sup>12</sup>*Cleaning Composition*, U.S. Patent No. 3,948,819 (filed June 18, 1973).

<sup>13</sup>Huang searched nanotechnology patents terms specifically related to nanotechnology, such as biomotor, molecular device, quantum dot\*, and nano\*. Patents that contained only the term "nanosecond" or "nanoliter" were excluded, and patents that contained more than one search term were represented just once in the study's accounting. Z. Huang et al. "International Nanotechnology Development in 2003: Country, Institution and Technology Field Analysis Based on USPTO Patent Database," 6 *Journal of Nanoparticle Research* 325-354, 326 (2004).

<sup>14</sup>Z. Huang et al. "Longitudinal Patent Analysis for Nanoscale Science and Engineering: Country, Institution and Technology Field," 5 *Journal of Nanoparticle Research* 333-363 (2003).

<sup>15</sup>Z. Huang et al. "International Nanotechnology Development in 2003: Country, Institution and Technology Field Analysis Based on USPTO Patent Database," 6 *Journal of Nanoparticle Research* 325-354 (2004).

not clear whether Huang et al., searched only issued patents, or whether they searched published patent applications, as well. Given that published patent applications are only available from 2001, however, it is likely that only issued patents were examined. Upon completing the search, Huang et al. reported 70,039 patents, the second largest number of nanotechnology patents. When they analyzed just the patent titles and claims, however, the number of reported patents dropped to 11,206.

Other studies reported numbers ranging from almost 4000 to fewer than 2000. These were largely studies that limited their search to just one part of the patent, such as the title or abstract. For those studies searching only the title of issued patents, Tullis found 2042 patents and Huang et al., found 1538 patents. For those studies searching only the claims of issued patents, Sampat reported that 3748 nanotechnology-related patents were issued between 2001 and 2003.<sup>16</sup> Lemley, repeating Sampat's method for 2004, identified another 1929 patents, for a total of 5677 patents.<sup>17</sup> Two research groups did not state which portion of the patent they searched. These are Lux Research, Inc., which identified 3,818 patents issued between 1985 and 2005,<sup>18</sup> and the Glänzel et al., study, which identified 3969 patents issued between 1992 and 2001.<sup>19</sup>

The studies reporting the lowest numbers were those that analyzed patents relating to a specific nanomaterial or application. A nanomaterial is any material created on the nanoscale. For example, a nanowire resembles a wire in that electrons are confined to move in one dimension, but the "wire" can be made from individual atoms and has a diameter on the order of nanometers. Lux Research, Inc., analyzed the abstracts and claims for patents relating to five different

<sup>16</sup>Sampat used the search terms provided in Huang's study. Huang, see footnote 13. B. N. Sampat, "Examining Patent Examination: An Analysis of Examiner and Applicant Generated Prior Art," NBER Summer Institute, Working Paper, 1-62, 24 (2004).

<sup>17</sup>Lemley criticized the Sampat study (and by extension, the Huang et al., study) by suggesting that Sampat's definition of nanotechnology was overly conservative, thereby underestimating the total number of nanotechnology patents. In addition, Lemley suggested that Sampat may have missed relevant nanotechnology patents when the search terms were located in the specifications, instead of the claims. Regardless, Lemley used the Huang et al. search terms for his general nanotechnology patent search. Huang, see footnote 13. M. A. Lemley, "Patenting Nanotechnology," 58 *Stanford Law Review* 601-630, 604 (2005).

<sup>18</sup>Lux Research, Inc., searched patent abstracts and claims for dendrimers, quantum dots, carbon nanotubes, fullerenes, and nanowires. Lux used these terms in conjunction with synonyms (e.g., "carbon fibril" or "carbonaceous cylinder" for carbon nanotubes). Lux did not provide an exhaustive list of the terms. Based on the patents Lux initially located, Lux identified key inventors and assignees and used those names to locate additional nanomaterial patents. Lux Research, Inc., "Statement of Findings: The Nanotech IP Landscape," Available at [http://www.foley.com/files/tbl\\_s31Publications/FileUpload137/2655/SOF\\_NTS-R-05-002.pdf](http://www.foley.com/files/tbl_s31Publications/FileUpload137/2655/SOF_NTS-R-05-002.pdf) (last visited June 14, 2006).

<sup>19</sup>Glänzel et al., did not provide search terms that would be recognized by the USPTO search engine. However, Glänzel et al., also performed a search of publications, using search terms similar to those employed by Huang. All microsystem-related technologies were purposely excluded. W. Glänzel et al. *Steunpunt O&O Statistieken*, "Nanotechnology: Analysis of an Emerging Domain of Scientific and Technological Endeavor," 1-73, 43 (2003). Available at [http://www.steunpuntoos.be/nanotech\\_domain\\_study.pdf](http://www.steunpuntoos.be/nanotech_domain_study.pdf) (last visited June 6, 2006).

nanomaterials, including dendrimers, quantum dots, carbon nanotubes, fullerenes, and nanowires. There were 1084 patents issued for these five nanomaterials through the beginning of March 2004. The ETC Group searched the Delphion patent database for issued patent abstracts to locate four types of nanomaterial patents.<sup>20</sup> It reported that 735 patents relating to some type of scanning probe microscopy (e.g., scanning tunneling microscopy or atomic force microscopy) were issued between 1982 and 2004. It also reported that 272 dendrimer-related patents and 146 quantum dot-related patents were issued between 1999 and 2004. The ETC's last case study focused on nanotubes, where it found 257 patents were issued between 1999 and 2004. This is in accordance with the Featherstone study, which identified nanotube patents by searching issued patent claims, and located just 206 in 2004.<sup>21</sup>

Only the ETC Group reported numbers for both published patent applications and issued patents combined. It searched the USPTO database for both published patent application and issued patent abstracts between 1999 and 2004, and identified 7004 such documents.<sup>22</sup>

Finally, of those studies that reported data for published patent applications, the numbers ranged from 42,293 applications, when Tullis searched the entire application description between 2001 and September of 2005, to 1235 applications when he searched just the title. Falling within that range were Lemley, listing 9184 patent applications between 2001 and 2004, and Lux Research, Inc., listing 1777 outstanding patent applications from 2001 until the date it compiled the report. The methodologies for the patent application searches are otherwise identical to those listed for the studies' issued patent search methodologies previously provided.

The Zucker and Darby study did not provide a specific number of nanotechnology patents, only relativistic data (i.e., the proportion of nanotechnology patents relative to nanotechnology articles), but the authors intend to make their results available on their online database, NanoBank, in the near future.<sup>23</sup>

<sup>20</sup>The ETC Group reported information for patents claiming quantum dots, dendrimers, and nanotubes, but they did not list the search terms used. For its analysis of atomic force or scanning tunneling microscope patents, ETC Group used specific terms, such as "atomic AND force AND microscope" and "scanning AND tunneling AND microscope." The ETC Group, "Nanotech's 'Second Nature' Patents: Implications for the Global South," 1-36, 21-29 (2005). Available at <http://www.etcgroup.org/documents/Com8788SpecialPNanoMar-Jun05ENG.pdf> (last visited June 6, 2006).

<sup>21</sup>Featherstone and Specht searched for issued nanotube patents by searching for the word "nanotube" in the claims. No alternate terms or nomenclatures, such as "nanocylinder," were used. D. J. Featherstone and M. D. Specht, "SKGF Nanotube Patent Study 2004," 1-22, 2 (2005). Available at <http://www.skgf.com/media/news/news.165.pdf> (last visited June 8, 2006).

<sup>22</sup>The ETC Group searched for the term nano anywhere in the patent or application abstract without any other terms or filtering. The ETC Group, "Nanotech's 'Second Nature' Patents: Implications for the Global South," 1-36, 7 n.11 (2005). Available at <http://www.etcgroup.org/documents/Com8788SpecialPNanoMar-Jun05ENG.pdf> (last visited June 6, 2006).

<sup>23</sup>Zucker and Darby searched nanotechnology patent titles and abstracts using two overlapping text searches, one with the string "nano" and the other using 475 nanoscale-specific terms, which were not provided in the study. They excluded all measurement terms, such as "nanometer" or "nanoliter" from their results. L. G. Zucker and M. R. Darby, "Socio-Economic Impact of Nanoscale Science: Initial Results and Nanobank," *NBER Working Paper Series* 11181, 1-31 (2005).

TABLE 15.1. Study Methodology and Results

Study	Dates of Examination	Type of Document Analyzed	Database Searched	Search Terms	Part of Document Searched	Number of Nanopatents
Tullis	1976–Sept 2005	Issued Patents Only	USPTO	"nano" selfassembl*, self-assembl*, atomic force microscop*, scanning tunneling microscop*, atomistic simulation, biomotor, molecular device, molecular electronics, molecular modeling, molecular motor, molecular sensor, molecular simulation, quantum computing, quantum dot*, quantum effect*, and nano* (excluding nanosecond and nanoliter).	Description Entire Patent	96,312
Huang	Jan 1976–Dec 2002	Unclear	USPTO			61,409 (number updated in 2003 study)
Tullis	Mar 2001–Sept 2005	Published Patent Applications	USPTO	"nano"	Description	42,293
Huang	Jan 1976–Dec 2002	Unclear	USPTO	same as in Huang (above)	Title + Claims	9,562
Lemley	Jan 2001–Dec 2004	Published Patent Applications	USPTO	same as in Huang (above)	Claims Only	9,184
Huang	Jan 2003–Dec 2003	Unclear	USPTO	same as in Huang (above)	Entire Patent	8,630
ETC Group	1999–2004	Published Patent Applications and Issued Patents	USPTO	"nano"	Abstract Only	7,004
Glänzel	Through 2001	Issued Patents Only	USPTO	Unclear	Unclear	3,969
Lux Research	1985–Mar 2005	Issued Patents Only	USPTO	Unclear	Unclear	3,818
Sampat	Jan 2001–Dec 2003	Issued Patents Only	USPTO	same as in Huang (above)	Claims only	3,748
Tullis	1976–Sept 2005	Issued Patents Only	USPTO	"nano"	Title Only	2,042
Lemley	Jan 2004–Dec 2004	Issued Patents Only	USPTO	same as in Huang (above)	Claims Only	1,929
Lux Research	2001–Mar 2005	Outstanding Published Patent Applications	USPTO	Unclear	Unclear	1,777
Huang	Jan 2003–Dec 2003	Unclear	USPTO	same as in Huang (above)	Title + Claims	1,644
Tullis	Mar 2001–Sept 2005	Published Patent Applications	USPTO	"nano"	Title Only	1,235
Huang	Jan 1976–Dec 2002	Unclear	USPTO	same as in Huang (above)	Title Only	1,196
Lux Research	1985–Mar 2004	Unclear	USPTO	Dendrimer, quantum dot, carbon nanotube, fullerene, nanowire; synonyms such as carbon fibril and carbonaceous cylinder; common assignees and inventors	Abstract + Claims	1,084
ETC Group	1982–2004	Issued Patents	Delphion	atomic AND force AND microscope; scanning AND tunneling AND microscope; scanning AND microscope; scanning AND probe AND microscope same as in Huang (above)	Abstract Only	735
Lemley	Jan 2001–Dec 2004	Issued Patents that are assigned to a University	USPTO	same as in Huang (above)	Claims Only	664
Huang	Jan 2003–Dec 2003	Unclear	USPTO	same as in Huang (above)	Title Only	342
ETC Group	1999–2004	Issued Patents	USPTO	Unclear; but relating to dendrimers	Unclear	272
ETC Group	1999–2004	Issued Patents	USPTO	Unclear; but relating to nanotubes	Unclear	257
Featherstone	Jan 2004–Dec 2004	Issued Patents Only	USPTO	"nanotube"	Claims Only	206
ETC Group	1999–2004	Issued Patents	USPTO	Unclear; but relating to quantum dots	Unclear	146
Zucker	Jan 1986–Dec 2003	Unclear	USPTO	475 "nano"-specific search terms, and the string "nano" (list unavailable; check NanoBank)	Title + Abstract	not reported

Table 15.1 provides information about each study's methodology and reported number of nanotechnology patents. Each study's data is reported separately.<sup>24</sup> Recall that important factors influencing each study's results include which portion of the patent was searched and whether the patent was an issued patent or only a patent application. The other key factor is the date of each study. A timeline (Fig. 15.1) has been created to put each study into chronological perspective. Figure 15.1 is not to scale, and is intended only to provide a rough guide for comparison purposes. The studies that searched the most restrictive field, the title, identified the fewest number of patents. Those searching the patent abstracts identified roughly as many patents as those who limited their search to the patent claims. In addition, most of the studies examining particular nanotechnology-related materials or products, such as fullerenes or dendrimers, reported between 200 and 300 patents. Although Lux Research, Inc., found 1084 patents relating to specific nanomaterials (e.g., quantum dots), this number was based on combining the total number of patents for the five different nanomaterials examined in the study.

### Beyond the Numbers: Emerging Trends in Nanotechnology Patenting

The studies described above focused largely on the total number of nanotechnology patents. In addition, however, they provide other data that illustrates how nanotechnology is affecting our society. For example, commonly addressed topics include whether the bulk of patents are obtained by companies, universities, or individuals, and whether more patents were obtained by U.S. or foreign entities. A few of the authors discussed in detail the common perception that nanotechnology patents are of poor quality and claim overlapping subject matter, and proposed solutions for remedying that situation. Each of these areas will be explored in more detail below. When weighing the information provided, recall that the studies vary in their methodologies and that no study addresses every issue.

One of the ways to predict how nanotechnology will shape the future is to determine which fields are experiencing the most patenting activity. Nanotechnology is unique in that any innovation in the field can potentially impact a variety of diverse technologies, such as electrical engineering and pharmaceuticals.<sup>25</sup> The USPTO divides all of the patent applications it receives into different technology centers based upon the primary technology used by the invention. Nanotechnology patents are found across all the technology centers, but are generally concentrated in just four. These include the "Biotechnology and Organic Chemistry" technology

<sup>24</sup>For example, when Lemley repeated Sampat's 2001–2003 search for the year 2004, the combined total was not recorded on the table. Similarly, Huang et al. repeated their team's 1976–2002 search for 2003, and the 2003 data are recorded separately. This both represents each researcher's work with greater accuracy and allows a more detailed look at the observable trends.

<sup>25</sup>See, e.g., *Method of Precise Laser Nanomachining with UV Ultrafast Laser Pulses*. U.S. Patent No. 7,057,135 (filed Mar. 4, 2004), which claims a method of making a microstructure. The microstructure, which has at least one feature that measures more than 200 nm, may be used as a coupled quantum dot device, a micro-electrical-mechanical system, a micro-surface-acoustic-wave device, a biochip for

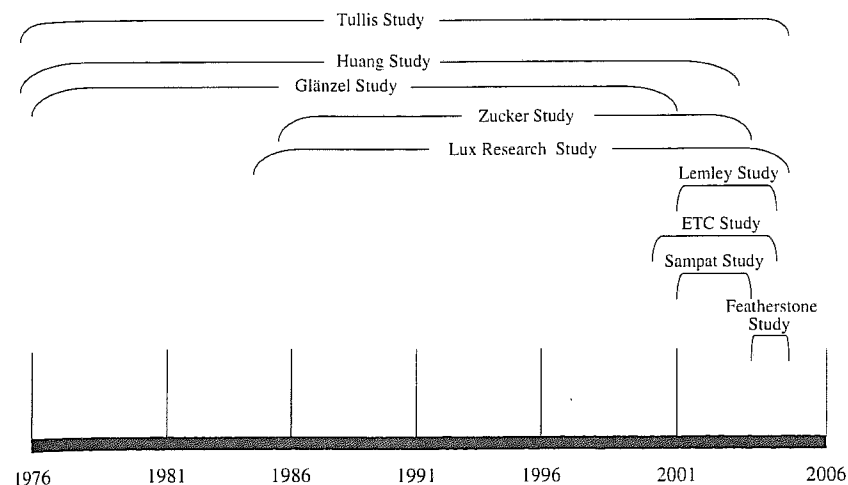


Figure 15.1. Nanotechnology patent study timeline.

center, which contains about 30% of the total nanotechnology patents; the "Chemical and Materials Engineering" center, which accounts for about 25% of the patents; the "Semiconductor, Electrical, Optical Systems" center, which contains 23% of the nanotechnology patents; and the "Mechanical Engineering, Manufacturing, and Products" center, which contains around 14% of the patents.<sup>26,27</sup> Together, these technology centers contain approximately 92% of all nanotechnology patents.

After the patent application is assigned to a technology center, it is assigned to a patent examiner. The examiners analyze the application to see if the USPTO should issue a patent. To do this, the examiners must first determine whether the application's invention has already been patented or described by another. Examiners assign a classification number to each application based upon the specific type of invention described therein. This allows examiners of new applications to easily identify the relevant patents and applications that they should search first as they determine whether the invention is patentable. These classification numbers provide a more detailed look at where the majority of nanotechnology patenting is taking place.

Three studies specifically determined which classes the examiners assign nanotechnology patents to most often. Glänzel et al., determined the top 10 technological

detection of hazardous chemical and biological agents, or a high-throughput drug screening and selection microsystem.

<sup>26</sup>B. Kisliuk, "Nanotechnology-Related Issues at the United States Patent and Trademark Office," presented at NC Nanotech 2006, March 9, 2006. Available at <http://www.ncnano.com/> (last visited June 6, 2006).

<sup>27</sup>D. J. Robeson, "Nanotechnology and the USPTO," *The Disclosure*, May 2006. Available at <http://www.napp.org/disclosure/> (last visited June 6, 2006).

classes between 1992 and 1999. They divided the patents into two data sets, one from 1992 to 1994, and the other from 1997 to 1999, to determine which areas were experiencing the largest growth. The study did not provide the precise USPTO classification, but listed the following ten areas in decreasing order of patent activity: semiconductors; surface technology and coating; analysis, measurement, and control technology; electrical machine and apparatus or electrical energy; optics; materials and metallurgy; macromolecular and polymer chemistry; chemical engineering; pharmaceuticals and cosmetics; and audiovisual technology. Although they found that each of the listed areas experienced absolute growth in later years, some areas experienced a decrease in their percentage of total nanotechnology patents. Glänzel et al., reported that the areas related to instrumentation, including analysis, measurement and control technology; electrical machinery and apparatus or electrical energy; optics; materials and metallurgy, pharmaceuticals and cosmetics, and audiovisual technology all decreased in share. For example, optics-related patents decreased slightly from 10.31 to 8.74%. On the other hand, semiconductors, surface technology and coating, macromolecular chemistry, and chemical engineering all gained a small percentage increase.

Huang et al., found that the nanotechnology patents they identified covered 423 out of a possible 462 patent classes. They also analyzed which classes were experiencing the largest growth in patent activity by comparing the resulting patent class dispersion for the year 2003 against the results from 1976 to 2002. They listed the top 20 patent classes and observed that the fastest growth for the year 2003 (as compared to the most prominent classes between 1976 and 2002) occurred in molecular biology and microbiology, bioaffecting and body treating drugs, processes for manufacturing semiconductor devices, and a certain class of organic compounds. Between 2002 and 2003, however, the class for active solid-state devices grew the fastest overall.<sup>28</sup>

The Featherstone and Specht study is consistent with these results. They found that the most common patent classes were for semiconductor device manufacturing, inorganic compound chemistry, electric lamp and discharge devices, active solid-state devices, and radiant energy. All but the inorganic compound class appear in the top 20 lists for 1976–2002 and 2003 by Huang et al. See Table 15.2 for a comparison of all three studies' results.<sup>29</sup>

Next, five studies reported data regarding which entities receive the largest number of nanotechnology patents. All of the reports agree that U.S.-based patentees and assignees receive the bulk of USPTO patents, and that companies and corporations are receiving the largest percentage of those patents. For example, Glänzel et al., reported the United States accounted for 46% of the nanotechnology patents issued by the USPTO between 1992 and 2001. In addition, they found that companies received almost 80% of the patents, followed by universities and

<sup>28</sup>The method of measuring the growth of each class used by Huang et al., may be skewed, as they compare overall patent classifications for 1976–2002 (a 26-year total) against the classifications used for the year 2003.

<sup>29</sup>The Glänzel et al., study did not provide a USPTO classification number.

TABLE 15.2. USPTO Subclasses with the Largest Number of Nanotechnology Patents

Rank	Glänzel	Huang (1976–2002)	Huang (2003)	Featherstone
1	Semiconductors	435—Chemistry: molecular biology and microbiology	435—Chemistry: molecular biology and microbiology	438—Semiconductor device manufacturing: process
2	Surface technology, coating	514—Drug: bioaffecting and body treating compositions	257—Active solid-state devices	423—Chemistry of inorganic compounds
3	Analysis, measurement and control technology	424—Drug: bio affecting and body treating compositions	438—Semiconductor device manufacturing: process	313—Electric lamp and discharge devices
4	Electrical machine and apparatus, electrical energy	428—Stock material or miscellaneous articles	514—Drug: bio-affecting and body treating compositions	257—Active solid-state devices
5	Optics	250—Radiant energy	424—Drug: bio-affecting and body treating compositions	250—Radiant energy
6	Materials, metallurgy	530—Chemistry: natural resins or derivatives; peptides or proteins; lignins or reaction	428—Stock material or miscellaneous articles	—
7	Macromolecular chemistry, polymers	536—Organic compounds —part of the class 532 - 570 series	436—Chemistry: analytical and immunological testing	—
8	Chemical engineering	438—Semiconductor device manufacturing; process	427—Coating processes	—
9	Pharmaceuticals, cosmetics	257—Active solid-state devices	530—Chemistry: natural resins or derivatives; peptides or proteins; lignins or reaction	—
10	Audio-visual technology	427—Coating processes	250—Radiant energy	—

(Continued)

TABLE 15.2. *Continued.*

Rank	Glänzel	Huang (1976–2002)	Huang (2003)	Featherstone
11	—	436—Chemistry: analytical and immunological testing	430—Radiation imagery chemistry process, composition, or product thereof	—
12	—	430—Radiation imagery chemistry process, composition, or product thereof	356—Optics: measuring and testing	—
13	—	359—Optics: systems (including communication) and elements	359—Optics: systems (including communication) and elements	—
14	—	356—Optics: measuring and testing	436—Chemistry: analytical and immunological testing	—
15	—	422—Chemical apparatus and process disinfecting, deodorizing, preserving, or sterilizing	385—Optical waveguides	—
16	—	204—Chemistry: electrical and wave energy	422—Chemical apparatus and process disinfecting, deodorizing, preserving, or sterilizing	—
17	—	252—Compositions	524—Synthetic resins or natural rubbers - part of the class 520 series	—
18	—	524—Synthetic resins or natural rubbers - part of the class 520 series	313—Electric lamp and discharge devices	—
19	—	546—Organic compounds - part of the class 532–570 series	204—Chemistry: electrical and wave energy	—
20	—	210—Liquid purification or separation	252—Compositions	—

other higher educational institutions at approximately 11%, and administrative or public institutions at almost 8%. Only 1.4% of the nanotechnology patents were either owned by individuals or not otherwise reported. Featherstone and Specht found that 51% of the 2004 nanotube patents were assigned to a U.S. entity, and that all but one of the eight most common assignees were companies or corporations. Huang et al., reported that 60% of USPTO nanotechnology patents were filed by U.S. entities between 1976 and 2003. The ETC Group reported 48% of the patents in 2003 were assigned to U.S. companies. Top 10 or top 20 lists of entities receiving nanotechnology patents are given in each of the studies listed above (i.e., Featherstone and Specht, Huang et al., ETC Group, Glänzel et al., and Sampat). Though the particulars vary, certain entities commonly appear on these lists. Tables 15.3 and 15.4 compare each study's findings as they relate to the top nanotechnology patent assignees. Table 15.3 lists the top nanotechnology patent owners or assignees reported by each study that addressed the question. Many of the entities appear in more than one list. Each of the entities is listed in Table 3 according to its rank. For example, if three companies tied for position four, then those companies would all be listed as fourth and the next available position would be position seven. If more than one entity received the same ranking, every other entity is italicized so that the full name of the each entity is clear. Table 15.4 sets forth the number of times each company was listed as a top assignee by each study.

A surprising trend is reported in three of the studies. Lemley found that, on average, 12% of inventors receiving a patent assigned their nanotechnology patents to a university between 2001 and 2004.<sup>30</sup> Across all fields, however, only about 1% of patentees assign their patents to a university, so the observed increase is significant.<sup>31</sup> The ETC Group and Glänzel et al., studies confirmed this result, finding that 11–12% of the analyzed nanotechnology patents were assigned to U.S.-based universities. The University of California accounted for a large portion of the patents, appearing on three of the top patent assignee lists (see Table 15.4).

Lemley also identified 10 of what he termed “building-block patents,” or patents on foundational technology, such as carbon nanotubes, semiconducting nanocrystals, and self-assembling nanolayers. Of these patents, universities held seven. This result could explain why universities own between 11 and 12% of nanotechnology patents overall. If universities are obtaining more foundational patents, and nanotechnology is new enough that the bulk of the research is still taking place at the foundational level, then it follows that universities would have an increasing proportion of nanotechnology patents. One would expect this disparity to resolve itself over time, as patenting activity moves away from foundational technologies

<sup>30</sup>To determine the number of patents obtained by universities, Lemley searched for the terms “university,” “college,” “trustee,” or “foundation” in the patent assignee field. However, he notes that the search may be both over- and under-inclusive. The search terms are over-inclusive because a “foundation” could refer to a private foundation as opposed to a university nonprofit organization; the terms are under-inclusive because a university-controlled patent may be held under a different name than that of the university (e.g., Competitive Technologies, Inc. acting as the patent owner for the University of Colorado). Mark A. Lemley, “Patenting Nanotechnology,” 58 *Stanford Law Review* 601–630, 615 n.69 (2005).

<sup>31</sup>M. A. Lemley, “Patenting Nanotechnology,” 58 *Stanford Law Review* 601–630, 616 (2005).

TABLE 15.3. Top Nanotechnology Patent Assignees or Owners<sup>a</sup>

Rank	Featherstone	Huang (1976-2002)	Huang (2003)	ETC Group	Glänzel	Sampat (rankings not explicit)
1	Samsung	IBM	IBM	Canon K.K.	IBM	IBM
2	Rice University	Xerox Corp.	Micron Technology, Inc.	IBM	Eastman Kodak	Micron Technology
3	Daiken Chemical Co.	Minnesota Mining and Manufacturing Co. (3M)	Advanced Micro Devices, Inc.	Silverbrook Research	Matsushita	Advanced Micro Devices
4	Hitachi, Ltd.	Eastman Kodak Co.	Intel Corp.	USA Hitachi, Ltd. Seagate Technology	Hitachi Ltd.	Xerox Corp.
5	Nakayama Yoshikazu	Motorola, Inc.	University of California	—	University of California	L'Oreal
6	Industrial Tech Res. Inst.	University of California	3M	—	Fuji Co.	University of California
7	Nantero	NEC Corp.	Motorola, Inc.	Micron Technology, Inc.	Toshiba K.K.	Motorola
8	Advanced Micro Devices, Inc.	Micron Technology, Inc.	Hitachi, Ltd. Xerox Corp.	Eastman Kodak Co.	NEC Co. Sony Co.	Eastman Kodak
9	—	Canon K.K.	—	Olympus Optical Co., Ltd.	Canon K.K.	General Electric
10	—	E.I. Du Pont de Nemours and Co.	Canon K.K. Eastman Kodak Co.	University of California Rohm and Haas Co. Polaroid Corp.	BASF	3M
11	—	General Electric Co.	—	—	U.S. Secretary of the Navy Sumitomo Phillips Corp.	—
12	—	Texas Instruments, Inc.	NEC Corp.	—	—	—
13	—	Hitachi Ltd.	Coming Inc.	Sony Corp. Molecular Imaging Corp.	Nippon Co.	—
14	—	U.S. Secretary of the Navy	Applied Materials, Inc.	—	L'Oreal	—
15	—	Dow Chemical Co.	Fuji Photo Film Co., Ltd.	—	Agency of Industrial Science & Technology	—
16	—	Toshiba K.K.	Matsushita Electric Industrial Co., Ltd.	—	AMD Lucent Technologies, Inc. Texas Instruments, Inc.	—
17	—	Abbott Laboratories	Lucent Technologies Inc. Texas Instruments, Inc.	—	Xerox Co.	—
18	—	Advanced Micro Devices, Inc.	—	—	Olympus Optical Co.	—
19	—	Massachusetts Institute of Technology	Genentech, Inc. Toshiba K.K. Massachusetts Institute of Technology	—	Dow Corp. Fujitsu Ltd.	—
20	—	Merck & Co., Inc.	—	—	Exxon Co.	—

<sup>a</sup>Rankings with more than one member are italicized to distinguish each member.

TABLE 15.4. Most Commonly Appearing Assignees on Table 15.3

Number of Lists on which Company Appears	Company Name
5	International Business Machines (IBM) Eastman Kodak Hitachi Ltd.
4	University of California Advanced Micro Devices, Inc. Xerox Corp. Micron Technology Inc. Canon K.K.
3	Minnesota Mining and Manufacturing Co. (3M) Motorola, Inc. NEC Corp. Toshiba K.K. Texas Instruments, Inc.
2	General Electric Olympus Optical Co. U.S. Secretary of the Navy Fuji Co. L'Oreal Lucent Technologies, Inc. Dow Chemical Co. Massachusetts Institute of Technology Matsushita Co.
1	Samsung Rice University Daiken Chemical Co. Nakayama Yoshikazu Industrial Technology Research Institute Nantero E.I. Du Pont de Nemours and Co. Abbott Laboratories Merck & Co. Intel Corp. Corning Inc. Applied Materials, Inc. Genentech, Inc. Silverbrook Research Seagate Technology Rohm and Haas Co. Polaroid Corp. Sony Corp. Molecular Imaging Corp. BASF Sumitomo Phillips Corp. Nippon Co. Agency of Industrial Science & Technology AMD Exxon Co.

and toward more advanced applications and marketable products. Although it is arguably beneficial that universities are on the cutting edge of this new technology, the fact that universities hold such a high percentage of nanotechnology patents may actually be cause for some concern.

Lemley reports that 60% of the publicly reported licensing deals in 2003 involved a university. All of these licenses were exclusive; in fact, the ETC Group reported that between 2003 and 2005 universities announced 20 nanotechnology patent licenses, and at least 19 were exclusive. In general, Lemley found that for the year 2003, universities granted exclusive nanotechnology patent licenses 89–100% of the time, whereas corporations or companies issued exclusive licenses around 50–67% of the time.<sup>32</sup> Nanotechnology-related patenting in universities may, therefore, be problematic, as it could restrict or limit future downstream research and development. There are two reasons why this may occur. First, exclusive licensing agreements inherently restrict innovation by limiting the number of researchers working on a given technology. Only the minds that happen to be employed by the particular company that obtained an exclusive license will be thinking about and analyzing the licensed technology. Second, universities own a relatively large portion of the foundational nanotechnology patents. These patented “building blocks” are applicable across many different technologies, not just the particular area in which the university researcher works. If the universities own a large number of nanotechnology patents and refuse to grant broad licensing rights to the foundational technology, fewer researchers will enter the affected fields, including those completely unrelated to the university researcher’s work, and development in these unrelated fields will slow.

Another oft-voiced concern is that a “patent thicket” is forming. A patent thicket is created when overlapping patents are issued within a variety of diverse industries, making it almost impossible to identify and obtain the requisite licenses. Lemley offers several examples of nanoscale technologies that have overlapping patents, including carbon nanotubes, semiconducting nanocrystals, and drug delivery nanoparticles. For example, Lemley referenced another study that found 306 nanotube patents, including 10 patents claiming the nanotube itself and 20 patents on nanotube production methods.<sup>33</sup> In addition, he argued that older patents claiming a submicron scale invention could technically claim nanoscale inventions, even when as a practical matter the two would behave very differently. This would be the case even when the first inventor was unaware of the special physical properties stemming from reduction of the invention scale to below 100 nm. If submicron patent claims apply to nanotechnology, the patent thicket will become that much more difficult to navigate.

In addition to patents overlapping each other, there is concern that a single patent may contain claims that are too broad. For example, the ETC Group points to patents

<sup>32</sup>Nor is it only universities that have a propensity for granting exclusive licenses. Tullis reported that in 2003, 12 of the 15 publicly announced licensing deals for nanotechnology-related patents were exclusive; in 2004, 17 of 20 were exclusive.

<sup>33</sup>J. C. Miller et al. *The Handbook of Nanotechnology: Business, Policy, and Intellectual Property Law*, 68–71, 224 (John Wiley & Sons: Hoboken, New Jersey 2005).

that claim one basic nanotechnology application, but cover large portions of the periodic table. In one patent, the applicant claimed a metal oxide nanorod made with any one of 33 different chemical elements.<sup>34</sup> Similarly, another quantum dot patent claimed semiconducting nanocrystals made from any of the elements contained within groups III–V of the periodic table.<sup>35</sup> The claims included semiconducting nanocrystals that resulted both from the *combination* of any of the claimed elements as well as the elements alone.

Some of the authors argue that overly broad claims in nanotechnology patents are caused by examiners' lack of experience with nanotechnology. Many pointed out that a number of different examiners analyzed the patents at issue, indicating that few examiners had experience with more than one or two nanotechnology patent applications.<sup>36</sup> Between 2001 and 2003, for example, Sampat found that 794 different primary patent examiners examined the nanotechnology patents he identified in his study. This represented almost *one-fourth* of the primary patent examiners employed by the USPTO during that time period. Similarly, Featherstone and Specht reported that 142 examiners analyzed the 206 nanotube patents issued in 2004. Only 33 of these examiners examined more than one nanotube patent. The ETC Group reported that of the 726 patents they examined, more than 290 different patent examiners had been assigned to examine the patents.

Sampat noted that the wide dispersal of nanotechnology patents across many examiners raises concerns that the examiners do not have the needed expertise to properly analyze nanotechnology patents. Patent examiners are usually assigned to specific technology centers and art units so that they can gain proficiency in examining certain types of patents. If nanotechnology patents are spread out over many examiners, none of whom have the opportunity to examine many nanotechnology patents, the concern is that they will not gain experience in this emerging technology and will allow patents of poor quality to issue. Certainly the studies' results described herein provide support for this concern.

A few of the studies made suggestions to avoid or mitigate the effects of a patent thicket. Tullis argues that a "government license defense" should be created. Under the Bayh-Dole Act, a federal funding agency reserves the right to obtain a royalty-free government license for any patented technology funded by the government. Tullis argues that the language of the Bayh-Dole Act, which states in part, "the Federal agency shall have a . . . license to practice or have practiced for or on behalf of the United States any subject invention throughout the world," could be extended to include any contractor being funded by the government. The contractor would then be "practicing for or on behalf of" the United States. Of course, this solution is only useful for those patents in which the federal government has an interest, and would not affect the bulk of nanotechnology-related patents.

<sup>34</sup>*Metal Oxide Nanorods*, U.S. Patent No. 5,897,945 (filed Feb. 26, 1996).

<sup>35</sup>*Preparation of III-V Semiconductor Nanocrystals*, U.S. Patent No. 5,505,928 (filed Apr. 21, 1994).

<sup>36</sup>For example, B. H. Sampat, "Examining Patent Examination: An Analysis of Examiner and Applicant Generated Prior Art," NBER Summer Institute, Working Paper, 1-62, 24 (2004); M. H. Heines, "Nano-Aerobics and the Patent System," 2 *Nanotechnology Law and Business* 335, 338 (2005).

Alternatively, Lemley suggests that the USPTO could implement the same strict utility requirement that already exists for chemistry and biotechnology patents to all patents, including nanotechnology-related patents.<sup>37</sup> In addition, the government could use the Bayh-Dole Act to require broad licensing of foundational nanotechnology patents. The Bayh-Dole Act allows the government to "march in" and "require the contractor, an assignee or exclusive licensee of a subject invention to grant a nonexclusive, partially exclusive, or exclusive license in any field of use to a responsible applicant" when, for example, the patent owner or licensee has not reasonably satisfied the public use requirements as provided by the federal government.<sup>38</sup> This solution, however, only applies to those patents supported by government funding.

The benefit to these methods is that each would shift activity away from foundational patents and towards "downstream implementations," though Lemley does not advise implementing such restrictions quite yet. He argues that because nanotechnology is still in a nascent stage, the incentive of obtaining broad patents may be needed to encourage researchers to invest their time and energy in developing the field. Instead, he recommends a few changes to key USPTO examination rules. First, he argues that the USPTO should not permit an unlimited number of continuation and continuation-in-part applications;<sup>39</sup> second, that the USPTO should publish all applications except those subject to secrecy orders;<sup>40</sup> and third, that treble damages should not be assessed against an inventor who independently invents an infringing product. Finally, Lemley believes that when a patent covers only a small component of a larger invention, an injunction should not be allowed to block the entire product.

## CONCLUSIONS

Some of the trends observed in these studies are perhaps expected. As far as the number of nanotechnology patents identified, the researchers that searched a greater portion of patent language tended to identify more patents. Researchers

<sup>37</sup>J. D. Forman, Comment, "A Timing Perspective on the Utility Requirement in Biotechnology Patent Applications," 12 *Albany Law Journal of Science & Technology* 647, 655 (2002). Forman discusses the USPTO utility examination regulations for biotechnology patents. These regulations were issued in large part as a USPTO response to the influx of patent applications for DNA sequences that did not have a known functionality at the time the application was filed.

<sup>38</sup>35 U.S.C. § 203(a)(3) (2000).

<sup>39</sup>An inventor files a continuation once his or her initial patent application is rejected by an examiner. This filing keeps the patent application pending, and as the applicant can file an unlimited number of continuations, he or she can theoretically keep his or her application pending for a very long time. An inventor files a continuation-in-part when he or she improves upon his or her initial invention and adds subject matter that was not disclosed in the initial application. In this situation, the applicant gets a new filing date for the added subject matter, but keeps the old filing date for the original disclosure.

<sup>40</sup>Inventors can "opt out" of U.S. publication if they promise not to file their applications in any foreign country which would publish the applications. An inventor might opt out so that if he or she ultimately decides not to obtain a patent, he or she has not widely disclosed the invention to others. Patent applications that claim inventions that are, for example, important to national security concerns may be designated "secret" by the USPTO and will not be published to protect national interests.

that searched a large span of time or that searched the USPTO database more recently also tended to report higher numbers; in addition, researchers that used broader search terms, such as "nano," generally reported higher numbers. Based on these trends, it becomes clear why Tullis' study identified more than 95,000 patents. He searched the entire issued patent description for the term nano in the USPTO database from 1976 to September of 2005.<sup>41</sup> In the same vein, the ETC Group reported the smallest number of patents when it searched patents issued over a 5-year period for terms specifically relating to quantum dots.<sup>42</sup>

Beyond numerical data, however, some preliminary conclusions may be drawn about how nanotechnology will shape our world. As can be seen in Table 15.2, certain technological fields have a disproportionate number of nanotechnology patents. The majority of top classifications fall into a few broad categories, such as chemistry, pharmaceuticals, optics, and electronics. Semiconductors appear as a main classification in each of the four studies listed in Table 15.2, and nanotechnology-related advances in this field are already reaching the market in products like the 90 nm microchip, which is currently being incorporated into computers and cellular phones.

In addition, most nanotechnology patents are assigned to U.S. businesses. Certain companies appearing consistently on lists of top assignees, like IBM and Eastman Kodak, are well positioned to take advantage of the nanotechnology boom and are expected to reap significant economic benefits from future product development. Although universities obtain a disproportionate number of nanopatents relative to the number of patents they receive in other fields, only two universities appear among the top assignees. Further, if universities are obtaining these patents as a function of doing foundational research, the percentage of patents issued to universities should decrease in the coming years as the basic tools of nanotechnology become well established, and a shift to creating marketable products occurs.

In contrast to most scientific or technological fields, where innovation in a particular field affects that field alone, innovations in nanotechnology have the potential to affect many different fields. This cross-field applicability provides a unique opportunity to determine whether early patenting activity can accurately predict the impact of a new technology on our future. Although some early trends have emerged, only time will tell whether we are truly experiencing another industrial revolution.

<sup>41</sup>T. K. Tullis, Comment, "Application of the Government License Defense to Federally Funded Nanotechnology Research: The Case for a Limited Patent Compulsory Licensing Regime," 53 *UCLA Law Review* 279, 282 (2005).

<sup>42</sup>The ETC Group, "Nanotech's 'Second Nature' Patents: Implications for the Global South," 1–36, 30 (2005). Available at <http://www.etcgroup.org/documents/Com8788SpecialPNanoMar-Jun05ENG.pdf> (last visited June 6, 2006).

### PART III

## NANOMEDICINE, ETHICS, AND THE HUMAN CONDITION

Many of the most exciting predictions being made for nanotechnology applications lie in the field of medicine. The prospect of imminent cures for cancer and other chronic and terminal disease has led to charges of hype and irresponsibility, though there would seem to be well-founded excitement in the research community that dramatic breakthroughs lie within reach.

Ethical issues arise especially in the context of the application of nanotechnology to medicine. It is the development of the discipline of "bioethics" that has been seen by many as offering the basis for a "nanoethics" that will enable the human community to grapple with ethical challenges that go well beyond nanomedicine.

Such issues are explored in this section. Nigel Cameron explores current American bioethics and questions its fitness to be the basis for a nanoethics unless it is reframed in a manner that leads it to draw on the substantive moral vision of our various communities and traditions, with their shared Enlightenment heritage. Debra Bennett-Woods reviews the broader implications of nanotechnology in healthcare from the perspective of a scholar and teacher with experience in healthcare administration. William Cheshire, a neurologist at the Mayo Clinic, reviews the prospects for nanomedicine, and assesses competing utopian and dystopian visions. Christopher Hook, Director of Ethics Education and a hematologist at Mayo, embarks on an assessment of nanomedicine with special reference to the goals of medicine and the treatment–enhancement distinction.