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Biotechnology, Technology Policy, and Patentability: Natural Products and Invention in the American System

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Part II.B.: Researchers - The Career Paths and Motivations of the "Inventor Class"

Part II.A has shown that the technology policy initiatives of the 1980s have succeeded in stimulating greater technology transfer and cooperative research among the government, university, and industry. Nevertheless, publicly funded research still dominates the basic research that produces the biotechnology-related inventions most likely to test the limits of patentability. This dominance of public funding would largely be an inefficient anomaly, however, if it was not accompanied by the fact that most researchers are strongly motivated by public sector values - values that prize the advancement and wide dissemination of scientific and technical knowledge, and, less altruistically, support a "credit economy" in which personal achievement is tied to status, reputation, and academic empire building. To the extent that public sector values are the dominant source of motivation for scientific and technological innovation, the need for the personal monetary inducements provided by patents is reduced. Moreover, given that publicly funded research naturally separates the government-university world of public sector values from the commercial world of more purely monetary inducement, where public sector values suffice to motivate research, public funding, as opposed to private investment, appears the natural way to provide most of the monies needed to enable research. [227]

For the above reasons, this Section examines the nature of what might be characterized as biotechnology's "inventor class" - the life science PhDs [228] who fill most of the inventive positions in the bioscience and biotechnology-related segments of government laboratories, universities, and industry. The evidence assembled suggests that, although there are significant exceptions, the "inventor class," and especially its subclass of younger members, still predominantly responds to traditional public sector values. Thus, although emphasis on inducement through intellectual property rights still retains some justification (even with regard to basic science), the federal government has substantial reason to suspect that, by expanding patentability, it may ill-advisedly substitute monetary inducements for the more central inducements from public sector values. [229] In short, given that public sector values still have a strong hold, an expansive patent law could interfere with the proper working of the American system in either of two ways. First, by increasing constraints from intellectual property rights, patent law could create impediments to research without creating effective countervailing motivations. Second (and somewhat more speculatively), by commercializing research, the government could drive away, or demoralize, those attracted by the relative asceticism of modern science. [230]

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[227] Of course, private firms can seek to create research "microcosms" that replicate the environments of university or government laboratories, while maintaining the commercial "macrocosm" that actually manages the business. However, the creation and maintenance of such research enclaves within the commercial world almost necessarily entails continuing costs and frictions greater than would be encountered in performing the same amount of research in a more uniformly "public sector" world.

[228] See infra note 231.

[229] Professor Rebecca Eisenberg argued in a 1987 article that patent law should pay attention to what this Article characterizes as public sector values. Eisenberg, Proprietary Rights, supra note 37, at 230. This Section of this Article provides empirical evidence to support a crucial premise of Professor Eisenberg's argument that public sector values are substantially heeded within the research community itself.

[230] After hearing a talk by Craig Venter, biochemist and President of Celera Genomics, a student at Harvard University was heard (by the author) to remark, "He sounded like a businessman, not a scientist," the dismissive tone making clear that the characterization was not meant as a compliment. See generally Venter, supra note 60.

1. The Career Paths of Life Science Professionals

To understand how best to motivate biotechnology's "inventor class," it is probably best to try to understand the career paths of its constituents. This Subsection points out several key aspects of the life cycles of bioscience PhDs, aspects suggesting that this class of individuals is likely to attract and to develop persons devoted to public sector values, especially early in their careers. In particular, this Subsection chronicles the employment patterns of life science PhDs, [231] with particular attention being paid to the ordinarily long and uncertain road that newly minted PhDs must travel before attaining positions of security and relative personal wealth. Key points are that scientific work - again, especially for younger scientists - often consists as much of drudgery as of glamour, and, perhaps partly as a result, that the work environments of life science PhDs are structured both to respond to and to shape attitudes based on public sector and academic values. All of the above suggests, this Subsection argues, that the scientific community, or at least significant segments of it, derives motivation from values quite different from those prevalent in the modern money economy. As suggested above, this conclusion has ominous implications for arguments to expand the scope of patentability - at least insofar as those arguments depend on the supposed need to motivate biotechnological invention.

The first step toward an understanding of the nature of the PhD com-munity [232] is to gain an idea of its size and structure. In 1995, industry employed approximately 24,000 life science PhDs, a total that represented a more than fourfold increase from the 5,500 employed in 1973. [233] Despite the increase in industrial employment, the total number of life science PhDs at the university is still much larger. In 1995, academic institutions employed 69,500 life science PhDs - 49,000 as faculty and 20,500 as postdoctoral fellows or staff. [234] Meanwhile, NIH itself employed about 2,000 PhDs in "permanent" positions, [235] as well as a few thousand postdoctoral fellows. [236] Although the employment distribution of life science PhDs will presumably continue to shift in favor of the growing bioscience industry, the supermajority of life science PhDs in government laboratories, universities, and research institutes appears safe for years to come. Consequently, the distribution of life science profes-sionals, with its strong tilt toward academia and government, bears a rough correspondence to the tilt already seen in the funding figures for basic science. The sense of such a tilt is only strengthened by the observation that the universities' laboratories play host not only to PhDs (faculty and postdoctoral fellows), but also to about 50,000 or so PhD candidates working on original research. [237]

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[231] Obviously both over-and under-inclusive, the category of "life science PhDs" is really only a rough proxy for "researchers in a biotechnology-related field." However, the "life science PhD" category appears the best available for the purpose of analyzing existing statistical data, especially given that life science PhDs dominate the kind of cutting-edge research with which this Article is most concerned, and, given that, since at least the late 1980s, a supermajority of new life science PhDs have been in such specifically biotechnology-related fields as biochemistry, microbiology, cellular and molecular biology, and pharmacology. See National Research Council, Trends in the Early Careers of Life Scientists 22 (1998).

[232] Of course, not all life science PhDs work in the life sciences: in the mid-1990s, only 57.4% were doing so. See National Science Board, supra note 42, at 3-12.

[233] See National Research Council, supra note 231, at 13.

[234] See id.

[235] See National Institutes of Health, NIH Almanac 1999, Professional Staff by Type of Doctoral Degree (1999).

[236] See National Research Council, supra note 231, at 27. The National Research Council reports that, in the mid-1990s, life science PhDs who had graduated 9 to 10 years earlier were 38% likely to have tenured faculty positions, 24% likely to have positions in industry, and 11% likely to be working in a government laboratory. See id. at 2.

[237] The National Research Council reports that in 1995 the median time required to obtain the doctorate was 8.0 years, see National Research Council, supra note 231, at 27, and the number of graduating PhD students each year was well over 7000 in the life sciences, and over 6000 in biomedical fields specifically, see id. at 21-22.

The above numbers concerning the institutional distribution of life science PhDs (and PhD candidates) give some sense of where these bioscience professionals are, but give less sense of their more specific workplace environments and career trajectories. In these latter regards, the first thing to recognize is that the career path of a life science professional can be, and increasingly is likely to be, a long and tortuous one. Those who would be life science professionals currently embark on a career of at least three stages: [238] (1) a primary training stage of seven or more years of graduate study; [239] (2) a secondary training stage of three years or more in non-permanent positions (typically, postdoctoral fellowships); [240] and (3) a third stage, often only reached in the professional's late thirties, in which he or she holds a "per-manent" position (such as, for example, a tenure-track faculty position). [241]

Naturally, in order to understand the motivations and mindsets of life science professionals, we must begin by studying the nature of the two training stages. Our first observation is that young life science professionals are in the wrong profession if they are in it for immediate cash. Life science professionals receive financial support during their decade-long training process, but until they achieve permanent positions, their level of remuneration is comparatively low. Most students pay for their doctoral studies through a combination of research and teaching assistantships and fellowships - forms of support that come from some combination of their schools and the federal government. [242] The amount of money that doctoral students and postdoctoral fellows receive (at least when netted against their graduate school tuitions) suffices for subsistence, but does not promote the accumulation of significant personal wealth. [243] In fiscal year 1999, for example, one of the fortunate winners of an NIH-funded National Research Service Award

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[238] Because life science professionals must apply for new positions in each of these three stages, and often multiple times within these stages, they face a long period of sporadic job insecurity, and, frequently, the need to move to substantially different geographic locations. Charlesworth et al., supra note 39, at 94 (1989) ("[A] career in international science means that you have to be footloose - like it or not.").

[239] For 1995 life science PhD recipients, the average time of graduate study was 8.0 years. See National Research Council, supra note 231, at 27. In the late 1990s, the time to PhD in molecular and cellular biology was somewhat shorter than average, but still - at about seven years - quite long, see id. at 14, particularly in comparison with the 1970 average, for the life sciences in general, of 6.0 years to PhD, see id. at 27.

[240] In 1996, more than 75% of new biomedical sciences PhDs planned postdoctoral studies. See id. at 27-28. Over 60% of life science graduates in the early 1990s faced more than two years of postdoctoral studies. See id. at 30-31. Five or more years as a postdoctoral fellow was reasonably likely. See id. at 2.

[241] See id. at 2. Of 1989 PhD graduates in the life sciences, only 30% held tenure-track faculty positions five to six years after graduation, see id. at 35, and 38% "still held postdoctoral or other non-faculty jobs in universities, were employed part-time, worked outside the sciences, or were among the steady 1-2% unemployed." Id. at 3. In terms of obtaining tenure-track faculty positions, the situation was much better 20 years before, when nearly 60% of PhD graduates had such positions within five to six years of earning their PhDs. See id. at 35. Furthermore, with regard to obtaining permanent positions within five to six years, the success of recent biomedical science PhDs was worse than average (when compared to the success of life science PhDs in general), although their 35% rate of success in obtaining faculty positions at PhD-granting institutions within nine to ten years of their PhDs was better than average. See id. at 43-46. The current figures for life science PhDs roughly follow those for biochemistry PhDs who received their degrees between 1982 and 1985. A recent study showed that these PhDs spent an average of 5.9 years in obtaining their degrees, 4.1 years between receiving their degrees and obtaining tenure-track positions, and 6.1 additional years before obtaining tenure. See Maresi Nerad & Joseph Cerny, Postdoctoral Patterns, Career Advancement, and Problems, 285 Science 1533, 1533-34 (1999). By 1995, 18% of the PhDs had tenured academic positions, and 16% had tenure-track positions. See id. at 1534.

[242] In 1995, only 22.2% of life science graduate students were not supported by federal or institutional payments. See National Research Council, supra note 231, at 26. In 1993, the federal government provided support to 53% of life science doctoral students. See National Science Board, supra note 42, at 5-29.

[243] See Holaday Statement, supra note 74, at 15 (stating that "the average Ph.D. or M.D. does not begin to earn a reasonable salary until after the age of 30" and is outpaced, salary-wise, by the standard plumber until his or her mid-thirties).

received a stipend of $ 11,700 per year if he or she was a PhD candidate, [244] and a yearly payment of $ 26,252 if he or she was a beginning postdoctoral fellow. [245] An NIH "raise" in fiscal year 2000 brought the latter figure to $ 29,916. [246] Notably, such low pay is usually lacking in perquisites, including healthcare benefits. [247]

During the "lean" training years, future and present life science PhDs work primarily in university laboratories. [248] These laboratories consist of a collection of discrete research groups comprised of up to a couple dozen researchers, primarily graduate students and postdoctoral fellows. [249] The graduate students and fellows typically work under the charge of a single "principal investigator" [250] - a permanent researcher who holds a full or associate professorship and who obtains the funding needed to run the laboratory. [251] Although the seniority of the principal is unquestioned, [252] the social structure of the laboratory is generally "quite free, permitting and even encouraging iconoclastic and innovative contributions from anyone in the group." [253] Nevertheless, although the environment may be relatively "socially free," a young researcher, whether in an academic or industrial laboratory, can expect a substantial amount of drudgery. The work is

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[244] See National Institutes of Health, The President's Fiscal Year 1999 Budget for NIH (Feb. 2, 1998) <http://www.nih.gov/news/Budget99/BUDGET99.HTM>. In 1998, NIH recommended that beginning post-doctoral fellows be paid just over $ 20,000 per year, and that five-year postdoctoral fellows be paid slightly less than $ 30,000 per year. See National Research Council, supra note 231, at 16.

[245] See Jeffrey Mervis, Cheap Labor Is Key to U.S. Research Productivity, 285 Science 1519, 1520 (1999). NIH stipends have become the benchmarks for compensation of postdoctoral fellows. See id. More experienced fellows earned slightly less meager sums in 1999: a postdoc with two years of experience received $ 32,700; one with seven or more years of experience earned the maximum stipend, $ 41,268. See id.

[246] See Maxine F. Singer, Enhancing the U.S. Postdoctoral Experience, 289 Science 2047, 2047 (2000).

[247] A recent article in Science described the situation as follows:

At the lower end of [the postdoctoral compensation] range, which is typical in academia for life sciences and some physical sciences, pay is embarrassingly inadequate: The beginning annual National Institutes of Health stipend [in fiscal year 2000], a common benchmark, is $ 29,916. Postdocs often have no standard health benefit package; many receive no coverage for their families and some must arrange coverage for themselves.

Id.

[248] See supra text accompanying notes 232-37.

[249] They can be larger, but, whatever their size, their organization is usually approximately the same. See, e.g., Gretchen Vogel, A Day in the Life of a Topflight Lab, 285 Science 1531, 1531 (1999). Laboratories in other countries have traditionally had a much higher percentage of "technicians" who are considered not of "scientist" rank. See Charlesworth et al., supra note 39, at 76-77.

[250] See National Research Council, supra note 231, at 18.

[251] See Charlesworth et al., supra note 39, at 76.

[252] Id. at 77 (describing American research laboratories as "feudal fiefdoms headed by a liege-lord to whom all owe allegiance," and that can be run "pretty much as [the liege-lords] wish," if the liege-lords can find the necessary funding).

[253] National Research Council, supra note 231, at 18. The conventional justification for the "free social structure" of the environments in which PhDs receive their training is that such environments best promote both the scientist-trainees' education and "the progress of science." Id. at 16-18; see also Lewis M. Branscomb, From Science Policy to Research Policy, in Investing in Innovation, supra note 25, at 112, 114 ("Researchers need an environment that favors risk-taking and allows them considerable latitude in setting research strategies."); Lewis M. Branscomb & Richard Florida, Challenges to Technology Policy in a Changing World Economy, in Investing in Innovation, supra note 25, at 3, 11 ("Scientific research is best performed under conditions that allow a lot of freedom to researchers … .").

demanding and frequently tedious: [254] in general, long hours are required, often at the mercy of a machine or ongoing experiment [255] and often without much prospect for immediate extra-laboratory credit. [256]

Life does get materially better in the third stage of the PhD's career, in which he or she settles into a "permanent" position. However, competition continues. If a life science researcher stays in academia after completion of his or her training, or if the researcher proceeds to the relatively academia-like **[*150]** environments of NIH, his or her next great challenges will be to obtain a permanent position [257] and then to secure the funding necessary to run a re-search group. [258] The "battle for grants" continues virtually unabated through-out the remainder of a researcher's career. [259] In the life sciences, the targets of most attention are the grants from NIH. [260] NIH currently supervises ap-proximately thirty thousand outstanding grants to individual principal investigators, with slightly fewer than nine thousand new individual grants to be provided in fiscal year 2000 alone. [261] Given that the average outlay for an individual NIH grant is approximately $ 300,000, [262] and that many institutions expect researchers to obtain "substantial portions of their salaries from grants," [263] competition for the grants is understandably fierce. The probability of success in an initial grant application is usually well under fifty percent, [264] and

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[254] Cf. Rabinow, supra note 169, at 81-84, 90 (describing researchers' frustration with the iterative process of sequencing DNA before the invention of the polymerase chain reaction ("PCR")).

[255] See Charlesworth et al., supra note 39, at 93 (observing that researchers' hours were long and erratic, often determined by experiments that "have their own logic which demands when the next stage must be performed").

[256] Thomas Cech used the following (admittedly "a bit exaggerated") scenario to illustrate the "fate" of graduate students, who typically work long hours but "often receive only passing acknowledgment" for their scientific contributions:

Your research director … is being congratulated for his stunning talk at a conference in Maui or Tuscany or Aspen. He talked about your work, using the slides you rushed to provide on 10 hours notice. Meanwhile, you're back in your windowless basement laboratory at 2 a.m. with a cold drizzle outside, waiting for your gel to finish running before you call it a day.

Thomas R. Cech, A Celebration of Life in the Trenches: Amersham Pharmacia Biotech and Science Prize for Young Scientists, 280 Science 15, 15 (1998); see also Rabinow, supra note 169, at 40-41 (quoting David Gelfand's description of his dissertation advisor as an individual who "worked from 11:00 a.m. to 4:00 a.m., seven days a week," and believed that "graduate students must work harder").

[257] This step has become more and more difficult in recent decades, with life science PhDs holding postdoctoral positions becoming a larger and larger pool of low-paid workers in insecure jobs, "competing with a rapidly growing pool of highly talented young scientists." National Research Council, supra note 231, at 3.

[258] See National Research Council, supra note 231, at 17; Interview with Douglas Melton, supra note 217 ("You don't do anything in my field without substantial grant support."). At "top-quarter" research institutions, nearly 80% of the faculty in biomedical fields had federal grant support in the mid-1990s?even before corrections are made for faculty who are no longer actively pursuing research. See National Research Council, Research-Doctorate Programs in the United States: Continuity and Change 39 (1995).

[259] See National Research Council, supra note 231, at 17 (describing the competition for grants as "intense for all investigators, young and old").

[260] See supra Part II.A. NIH has two basic criteria in its peer-reviewed grants process: scientific interest and practical or social importance, the latter being demonstrable, for example, through an argument that the research in question could lead to a cure for a specified disease. See Interview with Douglas Melton, supra note 217.

[261] See Eliot Marshall, Plan to Reduce Number of New Grants Tempers Enthusiasm for NIH Budget Hike, 287 Science 953, 953 (2000). There is competition for institutional grants as well, see Etzkowitz & Leydesdorff, supra note 160, at 117 (recounting Columbia University's hiring of a Washington, D.C., lobbying firm to pursue federal funding for its "National Center for Excellence in Chemistry"), but because individual grants dominate both financially, see supra Part II.A, and temporally (in terms of the time that investigators devote to obtaining them), see text accompanying note 265 - the discussion focuses on them.

[262] See Marshall, supra note 261, at 953.

[263] National Research Council, supra note 231, at 18; see also Charlesworth et al., supra note 39, at 77 (observing that NIH funds pay, at least in part, for the salaries of the researchers in a laboratory).

[264] See National Research Council, supra note 231, at 17.

preparation of grant applications can occupy as much as thirty to forty percent of a principal investigator's time. [265]

Nonetheless, despite the time they must spend in applying for grants and running their intra-university laboratories, principal investigators often manage to take advantage of opportunities to involve themselves in business outside the university. Since at least the late 1980s, a high percentage of senior researchers have supplemented their purely academic work with employment as consultants for private firms or, in more permanent consulting roles, as members of biotechnology firms' scientific advisory boards. These latter positions usually bring with them an equity interest in the company, as much as a few tens of thousands of dollars of personal income, [266] and (sometimes) an additional potential source of funding for research. [267]

Of course, a more direct way to obtain an equity interest in a biotechnology company is to leave academia for industry full-time, [268] a move that an increasing number of life science PhDs are making. [269] The work environments that life science professionals are likely to find in industrial laboratories are in some ways university-like, [270] although probably less academic and more mission-oriented (with the ultimate mission being commercial profits) than in the 1970s and 1980s. [271] In fact, there are significant differences from the university environment, some positive and some negative. From the per-spective of the typical life science researcher, one significant benefit is that the industrial environment tends to free a researcher from the bureaucratic tedium of grantsmanship. [272] Another significant difference, often perceived as positive, is that it tends to reward the individual, in both money and status, more on the basis of contribution to group success - such as on the basis of one's estimated "incremental contribution to corporate revenues and profits." [273]

On the other hand, there are negatives associated with private sector employment. Perhaps the most substantial concern is that, because of the ultimate need to produce revenue, the relative balance of research freedom and "mission control" is often in a state of flux, with management trying to balance investors' demands for intra-company discipline with a recognition that organizational flexibility is necessary not only to promote innovation, but even to attract good scientists in the first place. [274] In general, the above concern is a more specific manifestation of the broad observation that, although work in industry can offer more

[265] See Kenney, supra note 42, at 18.

[266] See Rabinow, supra note 169, at 29-30.

[267] See id. at 149-54.

[268] See Cohan, supra note 77, at 11, 38 (observing that technology leaders usually offer stock options, as well as opportunities for equity in "spinouts" based on an individual's work); Lynne G. Zucker & Michael R. Darby, Present at the Biotechnological Revolution: Transformation of Technological Identity for a Large Incumbent Pharmaceutical Firm, 26 Res. Pol'y 429, 444 (1997) (reporting that pharmaceutical firms can recruit star scientists with "an overall working-conditions/employment package which includes, for those with identifiable contributions to drug discovery, stock options which vest as the drug candidate progresses through clinical trials and FDA approval").

[269] See supra text accompanying note 233.

[270] See Rabinow, supra note 169, at 10 ("One of the hallmarks of biotechnology companies in the 1980s was precisely their attempts to produce a milieu that would facilitate exchanges between the university world and industry so as to minimize the cultural differences between them and to make productive and profitable use of science.").

[271] See National Research Council, supra note 231, at 57.

[272] See Rabinow, supra note 169, at 28.

[273] Cohan, supra note 77, at 11.

[274] See Rabinow, supra note 169, at 143-44. Cohan argues that successful technology companies "create an informal work environment that stimulates creative people," Cohan, supra note 77, at 26, but at the same time establish "clear linkages between strategic objectives, competitive strategy, and research projects," make research teams accountable for results on deadline, and encourage researchers to think like business managers, id. at 130.

immediate security or remuneration, the nature of the researcher's role within a company is necessarily more contingent, more subordinate to a company's individualized business demands, than the role of an academic researcher financed by public funds.

As the above review of the career paths of life science PhDs suggests, their professional trajectories are nothing if not variegated and complex. Nonetheless, there are some general aspects of those trajectories that can be used to shed light on the development of technology and patent policy. Of primary importance is the fact that bioscience PhDs' career paths are typically quite long and difficult, at least compared to the mix of workloads and monetary rewards that might be expected in careers in law, business, or finance. Accordingly, particularly with regard to the early stages of the typical life science professional's career, a natural question - and an important one for the purpose of optimizing patent law - is what motivates these individuals to take such a hard road and what keeps them on it. Once these questions are answered, we will be in a better position to assess how patent law can provide the combination of enabling monies and personal inducements to which biotechnology's inventors will best respond.

2. Motivations of Life Science Professionals

Having traced out the tortuous and, for a long time, relatively unremunerative career path of the average young life scientist, one might be prepared to believe that the only good explanation for his or her career choice is that he or she "drifted into [it] without much deliberate planning or forethought." [275] Such an explanation is unsatisfactory in two ways: (1) it fails to explain what motivates individuals to continue on the path, and (2) it gives no aid in structuring the incentives that patent law is supposed to provide researchers (beyond suggesting that no system of rational inducement is necessary or possible). Thus, this Section attempts to develop a more complete picture of what impels relatively rational actors along the various stages of the career trajectory sketched by Part II.B.1. Unsurprisingly perhaps, this Section also asserts that the motivations of researchers are manifold, and, further complicating matters, that an individual researcher's mixture of motivations is likely to change during his or her lifetime. More usefully and less trivially, this Section argues that "public sector values" are still primary motivators of scientific and technical development in biotechnology. Indeed, we shall see that industry itself recognizes the strength of these motivators and tries to tailor its practices to exploit and not offend them. It therefore seems entirely reasonable that national technology policy, and patent law in particular, should do the same.

What this Article calls "public sector values" is a set of priorities cultivated by the traditionally publicly funded system of scientific research in university and civilian government laboratories. At least as publicly presented, these priorities give "first tier" status to largely idealistic desires to contribute to scientific and technological progress. Nonetheless, these same priorities recognize important "second tier" values that are more self-centered and directed toward personal enjoyment, self-esteem, and individual triumph. [276] Finally, public sector values allow for a "third tier" of crasser personal interests. Although public sector values tend to denigrate the accumulation of large amounts of wealth, or an inefficient pursuit of power for its own sake, they certainly permit, and do not discourage, the attainment of at least a modest amount (or a modest chance to attain a large amount) of personal wealth and influence.

The "first tier" of public sector values, the set that the scientific community tends to promote as foremost, glorifies individual contribution to scientific and technological progress. The ethic of contribution - part of

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[275] Charlesworth et al., supra note 39, at 122.

[276] This middle category of values that are self-centered, but not based on the ability to direct or acquire an "other," represents an addition to Paul Rabinow's "venerable triad" of motivations: "money, power, progress." Rabinow, supra note 169, at 29. The values listed in this Article correspond with those discussed by Cinda-Sue Davis at a conference sponsored by the New York Academy of Sciences in 1998: "power and money," "self-confidence and self-esteem," "opportunity to change the world," "opportunity to teach and to mentor," and "achieving goals." Cecily C. Selby, Review and Summary of Part II Sessions, in Women in Science and Engineering: Choices for Success 131 (Cecily Cannan Selby ed., 1999).

what sociologist Warren Hagstrom characterized as a social practice of "gift-giving" [277] - commonly reflects a sense that professionals should show "a desire to serve others." [278] This value forms part of a traditional scientific ethos that views discoveries as the common property of science, with recognition and esteem being the sole external rewards for the discoverer. [279] Although the primacy of contribution is probably as much an ideal as a reality, it continues to have a substantial influence on life scientists' self-descriptions. [280] Scientists in the biomedical fields frequently claim a desire to contribute to scientific advance or, perhaps even more poignantly, the cure or treatment of disease. [281] Furthermore, the ideal of contribution has real-life plausibility as an explanation of young researchers' persistence on the substantially barren road (materialistically speaking) of their early careers. [282] Certainly, public sector science likes to acknowledge the tangible benefits that come from promoting altruism and asceticism among the young. As the National Research Council recently observed, "to the established investigator and the overseers of life-science research, the availability of large numbers of bright young scientists willing to work very hard for relatively little financial compensation is an asset that contributes to a remarkably successful enterprise." [283] From the require-ment of original work as a doctoral student through demands that grant seekers explain both the scientific quality and practical utility of their proposals, the scientific community reinforces these most useful "first tier" ideals. [284]

Nevertheless, as the need to buttress these ideals suggests, they cannot do the work of motivating biotechnology's inventor class by themselves. Instead, they must be supplemented by various modalities of personal satisfaction and progress. Prominent among these is the feeling of pure personal enjoyment that many researchers experience in working on an interesting problem, [285] in making a discovery, [286] in

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[277] See Warren O. Hagstrom, The Scientific Community 12-13 (1965).

[278] Id. at 19.

[279] See Robert K. Merton, Science and Technology in a Democratic Order, 1 J. Legal & Pol. Soc. 115 (1942), reprinted in The Sociology of Science 267, 270 (Norman W. Storer ed., 1973) (describing four "institutional imperatives" of science: universalism, communism, disinterestedness, organized skepticism).

[280] See Rabinow, supra note 169, at 13.

[281] When Harold Varmus resigned his position as director of NIH to become president of the Memorial Sloan-Kettering Cancer Center, he explained, "I wanted to be in a place where there was medicine and a prospect of seeing laboratory findings affect a patient." Marshall, supra note 184, at 382. Similarly, Robert Fildes, president of Cetus Corporation from 1982 to 1991, explained his decision to give up a postdoctoral position to begin a career in industry by saying, "I think one of the attractions of going back into industrial research in the pharmaceutical industry was to be able to work on science that could have an impact on how you treat disease." Rabinow, supra note 169, at 69.

[282] See supra Part II.B.1.

[283] National Research Council, supra note 231, at 4.

[284] Paul Rabinow suggests that such "reinforcement" may succeed: he writes that Nobel Prize winners were motivated to join biotechnology start-ups in part by their "discomfort that ideas in university settings rarely led directly to health-oriented results," despite the fact that they had for years dutifully "filled in the section on their grant applications (especially to NIH) concerning the practical utility of the proposed research for benefiting health." Rabinow, supra note 169, at 31.

[285] Biotechnology professor Leroy Hood explained his decision to begin work in immunology as follows: "I think the major reason was, number one, it was clear at the time that there were going to be beautiful systems for exploring the fundamental properties of the immune response … . But, equally important, it's a system that poses absolutely fascinating biological questions." Lewis Wolpert & Alison Richards, Passionate Minds: The Inner World of Scientists 38-39 (1997).

[286] See Hagstrom, supra note 277, at 16 ("Research is in many ways a kind of game, a puzzle-solving operation in which the solution of the puzzle is its own reward."). Carlo Rubbia, a winner of the Nobel Prize in physics, described scientists as "essentially driven not by … the success, but by a sort of passion, namely the desire of understanding better, to possess, if you like, a bigger part of the truth." Wolpert & Richards, supra note 285, at 197 (1997). Molecular biologist John Cairns answered the question, "What do you like about [doing experiments]?" in a less straightforward, but still revealing, fashion:

teaching or mentoring, [287] or in participating in a successful cooperative effort. [288] Somewhat in tension with this last source of enjoyment, but still an undeniable source of personal satisfaction, can be the pleasure that comes from a sense of individual success in a competitive enterprise, from "beating" one's peers either to the "right answer" or to the next rung on the academic ladder. [289] Opportunities for individual competitive achievement - for example, through obtaining a grant, advancing one's career, being first to make a discovery or obtain a particular research result, or winning an academic award or honor - exist throughout a scientist's working life, and are widely recognized as an intrinsic part of the traditional scientific "economy of credit," in which research is stimulated by reputational rewards for publication and priority. [290]

Finally, there is the set of interests that public sector values rank in their "third tier" - the interests of individuals in the more directly materialist economy of wealth and power. Although practicing scientists do not seek to command armies, as principal investigators they exploit, to varying degrees, the opportunity

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I don't quite know. An experimentalist I enormously admire, Alfred Hershey, said that what he liked about being in a lab was finding an experiment that works, and then doing it again and again and again. I rather like that. It's a curious life in the laboratory because if you do an experiment, in principle you do it because you don't know the answer. Because you don't know the answer you can't properly design the experiment. Eventually by messing around you arrive at a conclusion of how things are.

Id. at 95. Along like lines, even Craig Venter, a leading example of the modern entrepreneurial scientist, claims that, although the tens of millions he has made as head of Celera Genomics are welcome, his motivation is curiosity. See Richard Preston, The Genome Warrior, New Yorker, June 12, 2000, at 66, 81.

[287] See Helen C. Davies, Oh, If They Could Only See Us Now!, in Women in Science and Engineering, supra note 276, at 113 (describing the pleasure of mentoring); Selby, supra note 276, at 131.

[288] In an ideal sense, scientific research can be viewed as part of a collaborative enterprise, in which new scientific findings are, in Robert Merton's words, viewed as "products of social collaboration" and therefore "assigned to the community." Merton, supra note 279, at 273. However, many individuals find that, because of the emphasis on individual achievement in a competitive setting, see infra text accompanying note 290, scientific practice does not live up to this ideal. See Diane Hoffman-Kim, Women Scientists in Laboratory Culture: Perspectives from an Academic Scientist in Training, in Women in Science and Engineering, supra note 276, at 107 ("Many women are … put off by a reverence for exclusive individualism and a scorn for collaboration in the process of doing science."). Indeed, individual life scientists not infrequently cite a desire to do "interactionist, collaborative science" as a reason to prefer work in the biotechnology industry. Rabinow, supra note 169, at 44 (quoting David Gelfand's account of his reasons for joining Cetus Corporation); see also id. at 70-71, 114 (describing various life scientists' particular satisfaction with participating in or overseeing cooperative efforts in or with industry).

[289] In describing the atmosphere in Robert Langer's laboratory at Massachusetts Institute of Technology ("MIT"), Gretchen Vogel noted that, although Langer's laboratory dwarfed that of many biotechnology startups, there was a difference: "None of the workers get stock options, high salaries, or other lucrative financial inducements. Instead, they get paid in a different coin of the realm - the chance to publish in the world's top journals, and an edge in the race to become academic top dog themselves." Vogel, supra note 249, at 1531.

[290] See Biagioli, supra note 22, at 3-5; see also Hagstrom, supra note 277, at 22 (describing science as organized around the "exchange of social recognition for information," although scientists generally deny publicly that information is provided in expectation of a reward). The classic study of Bruno Latour and Steven Woolgar argues that the aim of scientific endeavor is more properly characterized as that of accumulating "credibility," a forward-looking measure of "scientists' abilities actually to do science," rather than "credit," a backward-looking reward for past achievement. Bruno Latour & Steve Woolgar, Laboratory Life 190-201 (2d ed. 1986). In their "capitalist" model for science, "the receipt of reward is just one small portion of a large cycle of credibility investment," having "no ultimate objective … other than the continual redeployment of accumulated resources." Id. at 197-98. Despite Latour and Woolgar's "credibility" argument, their work provides considerable evidence of scientists' desire for credit. Consider the explanation that they obtained from a scientist regarding the reasons for which he switched from medicine to biomedical research: "I wanted positive feedback proving my smartness … . I wanted a very rare commodity: recognition from peers." Id. at 190. Even Robert Merton's idealistic account of science recognized the significance of "credit" among scientists' concerns. Merton wrote about the rewards of eponymy (naming whole fields, laws, theories, or discovered objects or phenomena after scientists), scientific prizes, and historical recognition. See Robert K. Merton, Priorities in Scientific Discovery: A Chapter in the Sociology of Science, 22 Am. Soc. Rev. 635 (1957), reprinted in The Sociology of Science, supra note 279, at 286, 298-305. He also cited Charles Darwin's youthful ambition for status among his fellow scientists, as well as Darwin's anxieties about ensuring priority of publication. See id. at 305-06.

(alternatively understood as a professional necessity) to establish a small academic empire, one that they seek to sustain and enhance through continual applications for funding and the acquisition of new equipment and personnel. [291] Even for those researchers for whom direct supervisory powers carry little interest, there is still the felt need to have sufficient power to pursue one's own favored research ideas, [292] as well as the desire to place and promote one's former students and to influence the direction or subject matter of others' research (as by being a mentor, a member of an NIH peer review panel, or a member of a biotechnology firm's scientific advisory board). [293]

"Power" does not exhaust the list of "third tier" values. Also within the public sector's "third tier" are personal monetary concerns. Although traditionally at the bottom of scientific priorities, interests in using science as a route to personal wealth have, in the age and area of biotechnology, won a new and increasing acceptance. [294] Although some faculty still insist on the ideal of "an independent space for science, beyond the control of economic interests," [295] such straight "NIH persons" are no longer the norm. [296] Nonetheless, there remains substantial strength in the sense that pursuit of personal wealth should be and, indeed, is a relatively low priority for life scientists, albeit a priority that is now more openly acknowledged and acted upon. Consequently, even though academic scientists are forming greater ties with private firms, personal monetary considerations - such as potential profits from patents - still seem subordinate, at least when it comes to the performance of public sector research itself. [297]

Nevertheless, concern about the future vitality of public sector values is not unfounded. Undoubtedly, part of the reason for the frequent lack of eagerness to turn research into profit is that the chance of any individual patent, or handful of patents, being worth very much is quite small - particularly when the patent is an

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[291] See supra Part II.B.1.

[292] The National Research Council reports that a large cause of the disappointment of young life scientists derives from their sense that present job opportunities leave them without the expectation of ultimately being "able to establish laboratories in which they [can] pursue research based on their own scientific ideas." National Research Council, supra note 231, at 4; see also Rabinow, supra note 169, at 59 (quoting Tom White of Cetus Corporation as noting (with remembered pleasure) that part of the attraction of Cetus was that "the younger scientists had a strong say in policy"). This notion of "power" as "power to do research" accords with Latour and Woolgar's argument that scientists' seek to accumulate "credibility." See supra note 290.

[293] See Rabinow, supra note 169, at 30. Researchers can exercise power in a "negative" as well as an "affirmative" way: in addition to reporting the "special reward" of being able to mentor, Helen Davies observes that "another compensation that one can have is seeing that the tormentors get their just deserts." Davies, supra note 287, at 113. With regard to "affirmative" exercises of power, a growing biotechnology industry provides senior researchers with greater opportunities to "place" their students in good positions, possibly in firms with which the senior researcher is affiliated. Industrial employment has become an important "growth edge" for life scientists at a time when the pool of permanent academic positions has become stagnant. See National Research Council, supra note 231, at 47. The availability of such an alternative employment sector is probably more important for the happiness of younger, rather than senior, researchers, particularly in light of the "palpable" "feelings of disappointment, frustration, and even despair" that the National Research Council recently observed among young researchers in academic laboratories, id. at 4.

[294] Henry Etzkowitz describes a revolution in academic science that has produced a cooperative relationship between the traditional value of "extension of knowledge" and the new value of "capitalisation of knowledge." Etzkowitz, supra note 40, at 824 (internal quotation marks omitted); see also id. at 829 (internal quotation marks omitted) (quoting a professor as saying that biotechnology changed faculty attitudes toward "trying to make money").

[295] Etzkowitz & Leydesdorff, supra note 160, at 116 (internal quotation marks omitted) (quoting Henry Rowland, nineteenth-century physicist and president of the American Association for the Advancement of Science).

[296] Etzkowitz, supra note 40, at 830-31.

[297] See id. at 831 (describing "moderate involvement" technology transfer?meaning no more than toleration or post-invention "knowledgeable participation"?as the emerging academic norm); Guston, supra note 95, at 225 (recounting the General Accounting Office's 1992 finding that royalty sharing had not stimulated more patenting by federal scientists).

offshoot of basic research. Given the unpredictability of drug development, [298] it is common knowledge that the "expectation value" of any particular early-stage invention is quite low. [299] Indeed, if the hope is that a patent may lead to a marketable drug, the chance that an individual biotechnological invention will do so may be as low as 0.02%. [300] Thus, even researchers substantially motivated by hopes to supplement their personal income are likely to find conscious pursuit of patentable inventions a bad bargain. [301] Of course, if current trends continue, with patentability expanding its reach further into the realm of basic research and with the market for early-stage inventions becoming more lucrative, the interests of scientists in pursuing potentially profitable research will increase, and the possibility of the "corruption" of what has been a successful system motivated by public sector values will become correspondingly greater.

One might object to the above characterization of scientists' motivations on the grounds that the real picture is much more complicated. Whatever the precise role of individual monetary considerations, like most people, most scientists respond to a complex mixture of motivations, not necessarily clearly defined even within an individual's own mind. Life scientists often explain their career choices by reference to a blend of values that cuts indiscriminately across the three tiers described above. [302] Scientists might even claim that the interests peculiar to one tier merely serve to advance those of another: Henry Etzkowitz has observed that "scientists often say that monies made from commercialising their research will be applied to furthering their basic research interests." [303] Furthermore, and quite significantly, a scientist's priorities are likely to evolve over time. Nino Levy asserts that young researchers, meaning those in the first five to ten years of their career, are likely to make their highest professional priority that of gaining opportunities to do challenging work in cooperation with researchers possessing established reputations. [304] According to Levy, mid-career and senior researchers respond more to the prospect of relatively immediate rewards of status, organizational recognition, or income. [305] Thus, younger researchers appear to place an even stronger-than-usual emphasis on first and second tier interests, and third tier values become more significant later in researchers' careers, at the same time that opportunities for personal remuneration become more plausible.

Recognition of such complexities and subtleties in the motivations of life scientists is important and helpful. Nonetheless, a sense that life science researchers' interests are mixed and changing does not contradict the general model of public sector values, which concentrates on describing rough priorities, rather than identifying sharply defined and mutually exclusive desires. Indeed, under a system of public sector values,

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[298] The President of Neogen Corporation described attempts to predict which biotechnological inventions will prove successful as "a bit like trying to guess where lightning will strike next." Industrial Biotechnology: Hearing Before the Subcomm. on Tech. of the House Comm. on Science, 105th Cong. 48 (1998) (statement of James L. Herbert, Pres. & CEO of Neogen Corp.).

[299] A patent that attracts industry interest may earn its inventor a few tens of thousands of dollars from the initial licensing fee, but, given the small chances of a viable commercial product within the patent term, is almost never likely to generate substantial income from royalties. See Interview with Douglas Melton, supra note 216.

[300] See Holaday Statement, supra note 74, at 12 (stating findings of the Pharmaceutical Research and Manufacturers' Association).

[301] A senior researcher who wishes to supplement his or her university income might be much better off choosing to devote a few more days a year to consulting work, than channeling his or her research efforts to maximize the chance of a profitable patent. See Interview with Douglas Melton, supra note 217.

[302] Robert Fildes described his decision to accept a position as head of the American branch of Biogen in the following terms: "I got the bug. I mean, here's a chance to build something from scratch. Here's a chance to be on the cutting edge of science … and a chance to make a lot of money." Rabinow, supra note 169, at 73. Henry Erlich, who endured "lots of sleepless nights" because of his anxiety about "going into the profit-making commercial arena," explained his decision to join Cetus Corporation by saying, "If you find a project that is of real fundamental passionate interest to you, and if it also has the possibility for having some real practical commercial outcomes, then you have the prospect of a company project that really satisfies a scientist." Id. at 80.

[303] Etzkowitz, supra note 40, at 827.

[304] See Nino S. Levy, Managing High Technology and Innovation 49 (1998).

[305] See id. at 49-51.

in which individual interests in advancement appear in the lower tiers of priority, one would expect that individual actors would report a confused set of motivations?a blend of more narrow personal interests with the altruistic motives that garner the greatest public approval.

The phenomenon of "tier blending" leads to a natural question: Is the mixing of altruistic and egoistic values a tip-off that first and second tier values are really just a screen for crass individualism? Consideration of the advice given to business managers on how to motivate high-technology innovators suggests that the answer is "No." Instead of calling for managers to focus on offering bright people more money, management consultants such as Levy emphasize the importance of accommodating the "peculiar sensibilities" of "inventor-type people," who appear, according to his account, to show an abnormally high response to first and second tier values. [306] For example, Levy reports that such individuals are more attracted to businesses with highly competitive hiring criteria, than to those merely offering a higher initial salary, an observation that tends to support a belief that such professionals prefer the satisfactions of the second tier to those of the third. [307]

Levy is not alone in his observation that first and second tier values are important. Peter Cohan has observed that "top employees [at technology firms] are motivated by three things: the personal satisfaction of working on products that make a difference to society, the intellectual stimulation of working with people that they respect, and a chance to generate personal wealth in the process." [308] Even when the issue is disclosure of research, an area in which firms often "buck" public sector values by restricting publication, [309] the sense that firms need to respond to the "peculiar sensibilities" of "inventor-types" has had confirmation in practice. Lynne Zucker and Michael Darby cite the example of a United States pharmaceutical firm that has a liberal publication policy because the firm prefers to run the risk of losing some competitive advantages, rather than incur a more certain loss of attractiveness to top scientists. [310] Along the same lines, industry practice suggests that firms do not believe that increasing individual rewards for obtaining patents is the best way to motivate potential innovators. Companies tend not to pay employee-inventors more than nominal sums for their patented inventions: instead, employee-inventors typically receive their benefits through salary increases for general employment performance or through growth in the value of their equity interests in the company. [311]

Thus, industry itself acknowledges the effectiveness of the top tiers of public sector values in promoting innovation. Industry's corollary distrust of the "patent market" as a proper incentive for innovation is emphasized by the fact that, even in providing monetary incentives for invention, firms' policies on inventor

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[306] Id. at 28.

[307] Levy describes one company's success in using screening criteria to increase its attractiveness to recruits, despite the fact that its salary offers lagged those of other firms. See id. (quoting a company official as saying that "the challenge of being selected became so attractive in the eyes of the best candidates that it largely compensated for the initial salary difference").

[308] Cohan, supra note 77, at 38. This finding is consistent with Levy's conclusions.

[309] When biotechnology firms fund research at the university, they typically require that researchers keep their research results confidential at least until the filing of a patent application. See Blumenthal et al., supra note 65, at 371-72. When researchers accept jobs in industry, they often have to accept such restrictions as a condition of their employment agreement. See, e.g., Rabinow, supra note 169, at 57-59.

[310] See Zucker & Darby, supra note 268, at 438 (internal quotation marks omitted); see also Guston, supra note 95, at 239 (observing that some studies suggest that public sector disclosure norms "encourage[] the adoption of such norms in private R&D, to the benefit of the productivity of the latter").

[311] See Rabinow, supra note 169, at 133. Despite explicit congressional direction to the contrary, NIH has acted similarly. Although Congress mandated that it make researchers' success in bringing about technology transfer a criterion in personnel decisions, NIH has retained "scientific quality" as its primary criterion and relegated success in producing CRADAs to an indirect role within the scope of a traditional criterion measuring the resources that a researcher has assembled. See Guston, supra note 95, at 230.

compensation have tended to reflect a judgment that the firm, rather than the unfiltered (and presumably less knowledgeable) free market, should determine how great a reward an intra-firm innovator deserves.

Of course, public sector values are by no means a complete explanation for scientific and technological progress. Nor are they a perfect and "un-conflicted" device for stimulating scientific and technological advance. As the discussion of the values' second tier itself revealed, [312] they contain flaws and contradictions - such as the internal tension between science's collaborationist ideal and its individualist reality - that drive some researchers from the university to industry. [313] Individual competitiveness within academia is undeniable, and it is also undeniable that such competitiveness has led researchers to seek to handicap their rivals by sacrificing first tier values' emphasis on cooperation and free disclosure. In order to maintain a com-petitive edge, researchers have been known to give only delayed or incomplete disclosure of their results, [314] or to withhold materials necessary to repeat and extend their work. [315] Indeed, with regard to such "pathologically competitive" behavior, the peer-reviewed grants process itself can contribute to the problem, both because it can foster excessive competition and because, as might be expected from a process that looks to issues of feasibility, it may often "encourage projects which are likely to produce quick results rather than important basic work." [316]

Still, a more direct, and ultimately more troublesome, cause of pathological public sector behavior is biotechnology researchers' network of ties to industry. As noted briefly in Part II.A, increases in the ties between university scientists and private industry have led to new concerns about the temporary suppression of scientific discoveries and, perhaps even more alarmingly, about conflicts of interest in the writing of scientific articles that, for example, discuss potential drugs. [317] Moreover, the combination of university-industry and university-government ties has led to ownership disputes in which researchers are forced to

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[312] See text accompanying notes 285-90.

[313] See supra note 288.

[314] See Zucker & Darby, supra note 268, at 438 n.12.

[315] See Eisenberg, Proprietary Rights, supra note 37, at 197-98. Slander, theft, and fraud are other potential products of competitive pressure, uncommon but not unknown to the annals of science. See Merton, supra note 279, at 311-12.

[316] Charlesworth et al., supra note 39, at 77; see also Stokes, supra note 81, at 119-20 (alleging a bias in the grants process "toward existing rather than novel approaches, toward higher profile rather than lesser-known projects"); cf. Ellen Licking, Joined at the Genes? Zebra Fish May Help Explain the Keys to Human Diseases, Bus. Wk., Jan. 24, 2000, at 166, 166 (describing an MIT researcher's reliance on private funds at a time when the scientific establishment thought she "would be out of science in three years"). Craig Venter, who has employed private sector funding to prove the scientific utility of his gene sequencing approach, one that the NIH peer review process had rejected, would certainly support an assertion that the government grants process is suboptimal. See Venter, supra note 60.

[317] The New England Journal of Medicine recently determined that 19 articles that it had published violated the Journal's rule against allowing authors to discuss drugs sold by companies to which they had financial ties. See Constance Holden, NEJM Admits Breaking Its Own Tough Rules, 287 Science 1573, 1573 (2000). A deputy editor of a comparable British journal criticized the New England Journal's policy as unrealistic, saying, "It's almost impossible to find a very informed commentator on a medical topic who hasn't had money from the pharmaceutical industry." Id. Indeed, as early as 1992, a study performed by Tufts University and UCLA researchers found that of a selection of 789 articles written by authors from non-profit or academic research institutions that were published in scientific and medical journals in 1992, "at least one lead author had a financial interest in the results" reported in 267 of them. Brooks & Randazzese, supra note 190, at 381. Such financial ties were most frequent for articles in the life sciences. See id. Of course, the existence of financial ties does not necessarily mean that researchers do a supporting company's bidding. Recently, one group of researchers published experimental results showing that their corporate sponsor's HIV treatment is ineffective, even though the corporate sponsor tried to block publication unless a more favorable analysis of a portion of the researchers' data was included. See Carol Cruzan Morton, Company, Researchers Battle over Data Access, 290 Science 1063, 1063 (2000). Nonetheless, Sheldon Krimsky of Tufts University warns that cases in which investigators and their publishing journals "stand[] up to the supporting companies" are probably the exception, rather than the rule. Id. (internal quotation marks omitted).

pay careful attention to "funding lines" tracking who paid what for particular university inventions. [318] Money trail issues have thus become both more important and more pervasive. Although public sector values remain the dominant system for promoting basic bioscientific progress, the mixed nature of public sector values and the pressure on that mix from existing ties to government and industry make the functioning of this dominant system less than ideal.

Consequently, given Part I's emphasis on the move to spur technological development by the increased "propertization" of research products, Part II closes with a quandary. The public sector system for deploying funds and values still constitutes the core of the American system for producing biotechnology-related innovation. Not only does it make important direct and indirect contributions to most of the most significant biotechnology-related advances, it also produces, and to a greater or lesser extent conditions, almost all of the biotechnology industry's significant innovative people. Nonetheless, the American system is committed to, and substantially dependent on, the private sector's having a substantial role. On the margins, the private sector provides alternative routes for innovation and for employment of potential innovators. [319] More fundamentally, the private sector, as well as connections to it, provides a means for translating laboratory advances into marketable products. How should the roles of the two sectors be balanced?

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[318] See Jon Cohen, HHS Probes Genesis of Gene Sequencer, 287 Science 1374, 1374-75 (2000) (discussing a federal probe of the funding origins of DNA sequencing machines developed at Caltech).

[319] This latter role of industry is important for the morale of young researchers, who are sufficiently mathematically sophisticated to recognize that, with the number of university professorships increasing only slowly and with each university professor replicating himself or herself many times through the training of individual graduate students, permanent university employment as a scientific researcher has become increasingly unlikely.