

Careers and Contradictions: Faculty Responses to the Transformation of Knowledge and its Uses in the Life Sciences

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Abstract:

Drawing on interviews with more than 80 scientists on two university campuses, we create a typology that offers insights into how transformations in the nature and locus of life science innovation influence academic careers and work practices. Our analyses suggest that a strong outcome of increased academic concern with research commercialization is the appearance of new fault lines among faculty, between faculty and students, and even between scientists' interests and those of their institutions. We argue that life science commercialization is driven by a mix of new funding opportunities, changing institutional mandates for universities, and novel research technologies that bring basic research and product development into much closer contact. The rise of patenting and commercially motivated technology transfer on U.S. campuses stands to alter faculty work practices and relationships, while transforming the criteria by which success is determined and rewards are allocated. Through close analysis of interviews with four researchers who typify a range of academic responses to commercialism, we demonstrate emerging patterns of conflict and agreement in faculty responses to commercial opportunities in the life sciences.

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Introduction

The division of labor in the life sciences was once drawn between academic basic science and more applied, developmental research conducted in industry. This divide was never a sharp one, as translational and clinical research often fed back into basic science (Gelijns and Rosenberg 1994), and some key discoveries were made in industrial laboratories. But with fundamental breakthroughs in molecular biology and genetics and the rise of biotechnology, the old divide has been rendered obsolete. 'Commercial' scientists are at the forefront of research in the human genome, while 'star' academic scientists have been deeply involved in the creation of small science-based firms (Audretsch and Stephan 1996; Zucker, Darby and Brewer 1998). Consequently, academic and commercial life scientists are now members of a common technological community (Powell 1996). In this paper, we focus on the consequences of this transformation for academic careers in the life sciences.

Universities themselves are becoming major players in this new arena. Their new commercial role is underscored by huge increases in academic patenting (Henderson, Jaffe and Trajtenberg 1998; Owen-Smith 2000), growing revenues from intellectual property licensing, (Mowery, Nelson, Sampat and Ziedonis. 2000), academic forays into venture capital financing (Desruijsseaux 2000), equity ownership of faculty start-up corporations (AUTM 1998), and even prototype development (Jensen and Thursby forthcoming). As the once separate realms of the academy and commerce overlap, universities and academic scientists face a new constellation of challenges.

In a recent essay, Lita Nelson (1998), the long time director of MIT's successful Technology Licensing Office, highlights some pitfalls of increased university

involvement with intellectual property and commercial applicability, citing increased secrecy, limited availability of research tools, inappropriate licensing arrangements, biased or problematic tenure decisions, and conflicts among universities, their faculty, students, and research sponsors as potentially negative outcomes of the blurring boundary between the academy and industry. She concludes by warning that “[p]olicy fiats, changes in law, or even attempts to categorize intellectual property and the “appropriate” handling of them [sic] are very likely doomed to have overly broad effects with harmful unintended consequences” (L. Nelson, 1998: 1461). Her warning reflects the difficulty of controlling (or even systematically categorizing) diverse routes to academic commercialization. She also suggests that strong interdependencies across those avenues create a complex, tightly coupled system highly susceptible to unintended consequences.

We also argue that changes to university and academic work practices are too broad and variegated to fit easily within a single explanatory rubric. Our goal in this paper is to survey the multiplex relationships involving faculty and examine the complicated tensions inherent in faculty responses to increasing academic commercialization. Analysis of faculty responses to the changed landscape allows us to (1) map faculty's varied involvement in commercial endeavors, (2) assess the effects faculty perceive commercialization to have had on the university and on academic science, (3) explore the strategies that scientists use to mitigate the negative consequences of these changes, and (4) weigh the complex attitudes and relationships among differently positioned faculty. The latter effort enables deeper consideration of the complicated conflicts and coalitions that form in response to attempts to control or encourage academic involvement in commercial endeavors.

Changes in opportunities for research funding (Feller 1990; Chubin 1994), expanded possibilities for university scientists to conduct research that crosses disciplinary and institutional boundaries (Powell and Owen-Smith 1998; Croissant forthcoming), and an increasingly fuzzy demarcation between basic and applied biomedical science (Narin, Hamilton and Olivastro 1997; Owen-Smith 2000) have created a new environment for academic work. The traditional view of the university researcher as a dedicated and disinterested, though passionate, searcher for truth is being replaced in the life sciences by a new model of the scientist-entrepreneur who balances university responsibilities and corporate activities in the development of new compounds and devices designed to improve human health and garner market returns for the investigator, the institution, and investors.

While the changes underway in academic life science are widespread, we argue that considering their outcomes in terms of a simple dichotomy of “new school” scientist-entrepreneurs against “old school” ivory-tower traditionalists misses much of the interesting variation in faculty responses to the changing institutional environment. New and old school faculty can be found at every research university; but some faculty evince both new and old school characteristics. Thus, following Dasgupta & David (1994: 495), we argue that “[w]hat matters is the socio-economic rule structures under which the research takes place, and, most importantly, what the researchers do with their findings.” Consequently, individual faculty choices in response to a shifting academic terrain have created a myriad of positions that are neither old nor new school, but instead combine characteristics of both.

In an attempt to systematically explore the characteristics of the middle class within the class structure, sociologist Erik Olin Wright (1984) developed the concept of contradictory class location. We find his concept of a contradictory position quite useful in accounting for variations in faculty responses to academic research commercialization. In Wright's terms, our difficulties in using the old school – new school dichotomy to parse diverse faculty responses results not from ambiguity, but from the fact that our informants simultaneously partake of multiple logics to justify their activities.

Wright (1984: 44) argues that “[a]mbiguity suggests that the problem is taxonomic, some people don't fit the slots properly; contradictoriness, on the other hand, suggests that the slots themselves have a complex character that can be identified as internally contradictory and given a positive theoretical status.” In this view, our difficulty in unequivocally placing a majority of faculty in either the old or new school categories suggests the failure of this dichotomous typology to account for the complex array of positions that faculty take in response to changes in the nature of life science research. Ambiguity suggests a lack of clarity or murkiness. Far from lacking coherence, the scientists we interviewed were keenly aware of current tensions and controversies and are developing well-reasoned assessments of the complex and rapidly changing worlds in which they work.

Our task, then, is to explain how transformations in the nature and locus of technological innovation influence academic careers and work. There has been some discussion of a growing norm of entrepreneurialism among faculty (Etzkowitz and Peters 1991; Slaughter and Leslie 1997) and evidence of an accumulative advantage process in which faculty with high academic status are afforded greater opportunities in the

commercial realm (Powell and Owen-Smith 1998). But we have only limited knowledge of how these developments shape relationships between faculty, among faculty and students, and between faculty research agendas and universities' commercial interests. Nor do we have much understanding of how evaluative criteria are being transformed by shifts in the division of labor between the academy and industry. Finally, we lack knowledge of the paths by which alterations to university policies and organizational practices may ramify through the academy, resulting in, as L. Nelson (1998) warns, significant unintended consequences.

To begin answering these questions, we draw on interviews with scientists at two major research universities to empirically ground our development of a typology of faculty responses to the changing division of labor. By taking seriously Wright's relational focus¹ on positions, our typology enables us to shed light on how broad technological changes in the nature of scientific knowledge (i.e. new research methods and combinations of once separate fields such as computer science and genetics) are influencing scientific career patterns, and to better understand how changes in organizational arrangements (e.g. increasingly complex university-industry collaborations, dual entrepreneurial and academic faculty roles, and multiplex academic involvement with commercial endeavors) are effecting the nature of faculty life. Our goal is to explain how taken-for-granted narratives about academic careers and membership in the academy itself are changing, and understand whether faculty who are differently positioned with regard to industry and research commercialization are developing varied

¹ By relational, we want to underscore that positions in social structures are defined by relationships, not by the attributes of individuals. Without the old school, there would be no new school.

interpretations of what careers and research programs look like. In short, we explore how high-profile life sciences researchers are navigating in this new arena.

Faculty types and exemplars: a typology of responses to the changing division of labor.

We have been interviewing faculty at research universities about the purported changes in the nature of academic research work in the life sciences.² We sampled faculty based on scholarly preeminence (reflected by holding a named chair and/or membership in the National Academy of Sciences) and entrepreneurial engagement (reflected by significant patenting activity and/or principal roles in start-up companies). We identified prestigious and prolific faculty from archival sources and used them as starting points for snowball sampling.³ Owen-Smith conducted more than seventy semi-structured interviews with academic scientists and research administrators, following a standard interview protocol. Generally ranging from one to three hours in length, these interviews were openly recorded and directly transcribed. Powell has spoken with fifteen faculty on a more informal basis.

We draw from all these interviews and Owen-Smith's observational field work in framing this paper, but find it especially useful to invoke an unconventional reporting strategy. In order to take full advantage of the richness of interview material in elucidating a typology of faculty responses to the new reality of academic life science

² Each of the four interviews examined here is based on formal interviews with individual scientists. Some details of personal biography and work setting are not reported to maintain subject confidentiality.

³ This strategy over samples very successful, elite scientists. Our arguments in this paper are tailored to demonstrate the wide variance in responses to commercialization among the most established and successful life scientists. We do not dispute the possibility that the trends we identify fail to fully capture the concerns of less successful researchers. Instead, we suggest that wide variance in beliefs among a small elite suggest even more varied responses when the views of junior and less successful senior scientists are considered. We do not attempt to exhaustively describe life scientists responses in this paper. Instead, we highlight the complexities and interesting points of contact of a small but important sub-set of those researchers.

research, we focus particular attention on four accomplished scientists who stood out in several respects. First, these faculty were especially informative and articulate about the new challenges facing life sciences researchers. Second, the positions these scientists represent typify the views of the great majority of the informants with whom we spoke. Their views, positions, and arguments, are, in that sense, ideal types.⁴ By systematically comparing these scientists' positions, we shed light on points of convergence and conflict in the larger arena of university-based life science. We turn to close analysis of these particularly rich transcripts to illuminate the attitudes and concerns of tenured life science faculty whose individual voices capture distinctive responses to university research commercialization apparent in interviews and field notes. Close comparisons across these four ideal-typical conversations highlight the tensions and inconsistencies arising from current technology transfer practice in university settings.

In order to facilitate such comparisons, we array our four faculty cases on a two by two table by appeal to their expressed beliefs on two dimensions: (1) whether or not academic life science is threatened by increasing research commercialization, and (2) how much overlap there is between the once separate realms of academic and commercial science. Figure 1 lays out the key lines of agreement and disagreement among four types of life scientists, emphasizing both the old school – new school dichotomy and a pair of 'hybrid' positions that partake of both. We then highlight the points of consensus and contention between these four scientists and, in so doing, illuminate some of the critical debates and transformations currently unfolding in the world of biomedical science.

⁴ By ideal types, we mean a set of views that accurately capture a coherent and distinctive position or opinion held by multiple informants.

In the terms we used earlier, the main diagonal of Figure 1 represents the dichotomy between old and new school faculty. In our simple formulation, the more traditionalist faculty position is characterized by a strong belief that the academy and industry are/should be distinct and a concern that commercial endeavors threaten university science. Faculty who hold this position typically do not pursue patents or commercial gains from their findings, preferring instead to pursue success strictly in the academic arena. In some ways, these faculty hope to maintain a conventional (but possibly fictional) academic world. This view of academic community is well characterized by R.K. Merton's (1976) four norms of open science: communalism, universalism, disinterestedness, and organized skepticism.

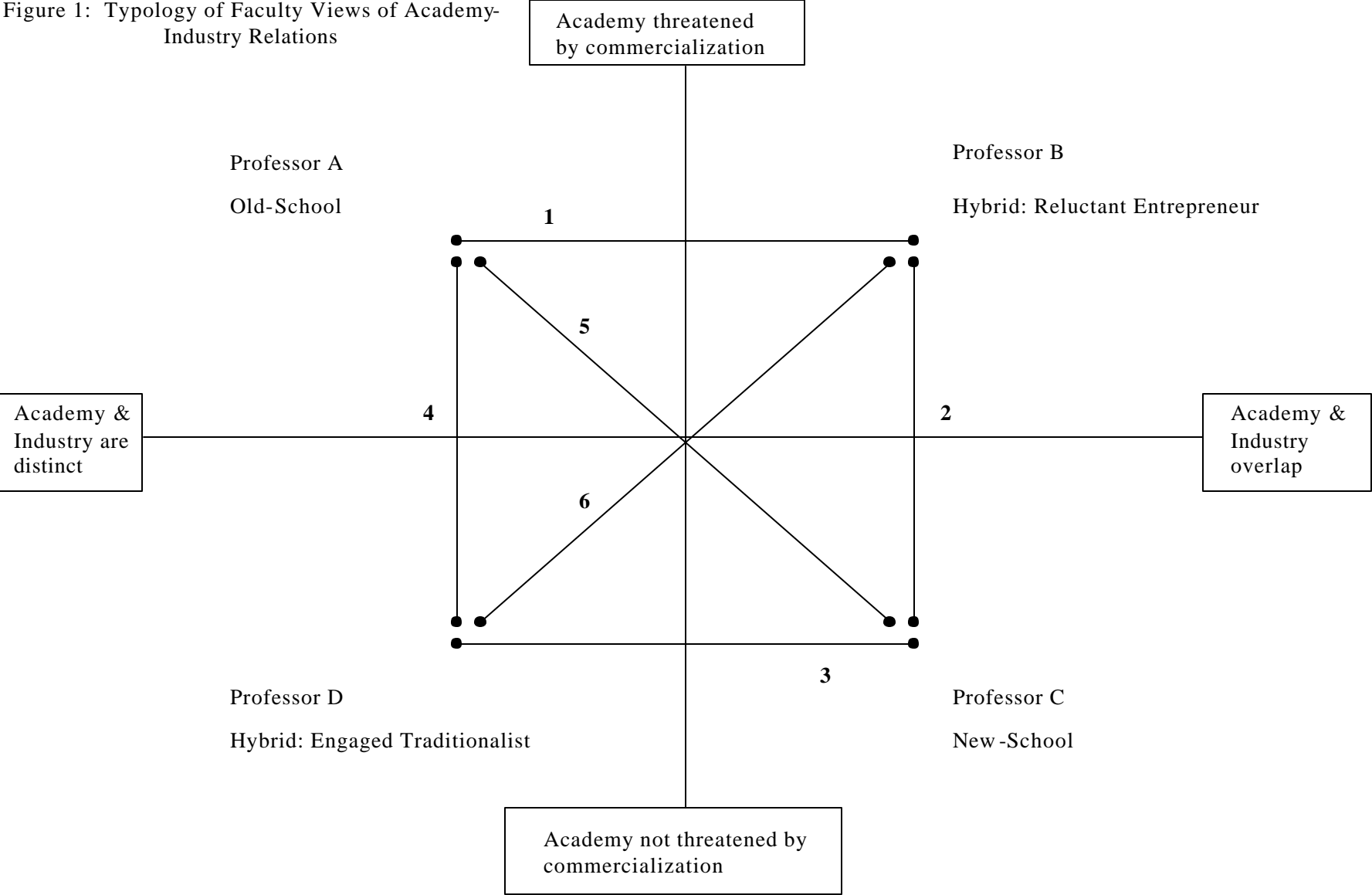
In contrast, the new school, or entrepreneurial, faculty position is characterized by recognition of a growing convergence between the academy and industry and a conviction that commercial engagement does not threaten university science. For faculty of this type, commercial and academic endeavors are difficult to separate and success in either realm is largely dependent upon achievement in the other. For the most entrepreneurial 'new school' faculty, the argument that academic life science might be threatened by commercialization is almost nonsensical.

To these researchers, academic science *is* inherently commercial and vice versa. Successful research, in their view, requires the mobilization of both academic and industrial resources in collaborations that span organizational locations. Bringing research programs to fruition means more than the publication of papers detailing new discoveries; instead new school scientists conceive of scientific discovery as a process that is intimately linked to the speedy development and delivery of new medical

treatments. For these faculty members, multi-disciplinary, multi-institutional collaborations are necessary tools in the production of knowledge (Gibbons et. al. 1994).

[Figure 1 here]

Figure 1: Typology of Faculty Views of Academy-Industry Relations



The off diagonal of Figure 1 represents hybrid positions that combine elements of both the old and new school. These strange bedfellows often agree in their perception of trends but have different interpretations of, and responses to, the changes they see. Because of their contradictory positions, ‘hybrid’ faculty often express uneasily paradoxical views on the changing nature of the academy. The internal conflicts apparent in their beliefs stem not from confusion but from attempts to coherently respond to the dictates of cross-cutting challenges.

Consider the hybrid faculty we dub ‘Reluctant Entrepreneurs.’ Scientists of this genre share the new school conviction that divisions between academics and industry are, at best, indistinct, while maintaining the old school belief that commercial endeavors threaten unique characteristics of the academy. These scientists hold a pragmatic and individualist view that leads them to aggressively patent findings through their academic institutions in a proactive attempt to protect the autonomy of their research from commercial encroachment. Somewhat paradoxically, these faculty are often aggressively entrepreneurial in service to the traditional norms and values of the academy. Their concerns with secrecy, industry encroachment, and commercially based restrictions on inquiry place them in positions similar to analysts such as L. Nelson (1998) and Blumenthal and colleagues (Blumenthal et. al. 1992; Campbell et. al. 2000) who see parallel dangers in proprietary university research.

The other hybrid position, which we dub ‘Engaged Traditionalism,’ also manifests the complex characteristics we expect of hybrid positions. Scientists who fall in this category share the old school belief that the academy is a special world, governed by well understood rules designed to advance and validate discovery. But these scientists also hold that commercial endeavors do not threaten the characteristic culture of the academy, a view that often leads them

to pursue ‘external’ commercial endeavors, consulting and patenting on their own time and maintaining, at least in their own minds, a sharp distinction between academic and commercial endeavors.

Where ‘Reluctant Entrepreneurs’ use activities they believe endanger academic science to shore up university-based research, ‘Engaged Traditionalists’ belie their own strong distinction between academic and industrial pursuits by turning prodigious academic reputations to the pursuit of commercial gain. While sharing the academic exceptionalism of the old school, these scientists take the individualist view that personal commitments to academic values enable scientists to reap largely separate benefits from commercial and academic endeavors. Like reluctant entrepreneurs, engaged traditionalists depend on situational and individual logics to navigate changing institutional waters.

We use Figure 1 to highlight six of points of comparison across these four positions and draw on the comments of four faculty exemplars to provide empirical flesh to the typological skeleton it represents. Relationships between the views held by Professors A and B, for instance, are represented by line number 1, overlaps between the attitudes expressed by Professors B and C are represented by line number 2, and so on. Close examination of similarities and divergences in the interviews along these six ‘fault lines’ comprises the empirical work of this paper.

Before empirically grounding our typology, however, it is necessary to introduce our four faculty exemplars. Professor A, an old school researcher, is a senior life scientist who occupies a prestigious named chair and directs a research division at a major university. While the neuroscience research conducted in his large, multidisciplinary laboratory has many potential commercial applications, Professor A has never pursued a patent on research findings or become

involved in a start-up firm. Professor B, the reluctant entrepreneur is a more junior tenured faculty member than Professor A. While he too occupies a prestigious university chair, his administrative duties are much more circumscribed. His genetic and biochemical research innovations have led to more than five patents, all of which are assigned to the university where he works. Professor B has never started a company and prefers to avoid consulting deals and industrially sponsored research.

Professor C, who represents the new school, is the youngest of the four scientists. He is a tenured faculty member in a department dedicated to translational research. Professor C's lab conducts a great deal of commercially viable research, evidenced by his multiple patents and involvement with a successful biotechnology start-up. While Professor C chooses not to hold a position on the company's board of directors, he is the board's chief scientific advisor and drives most scientific and technical decisions at the firm while maintaining his university position. Professor D, the engaged traditionalist, also occupies a named chair and has equivalent administrative duties to Professor A. His career of high impact research has led to his induction into the National Academy of Sciences. Where Professor A has not attempted to commercialize his research findings, Professor D is an inventor on more than ten patents, all of which are assigned to a biotechnology company he has worked with closely over the years.

Despite the differences among these scientists, they are similar in many important respects. All are exceedingly accomplished, and all are white men. All are tenured at major research institutions, hold Ph.Ds and in some cases MDs from high profile graduate programs, and have prestigious positions as directors of large laboratories employing numerous post-doctoral fellows, graduate students, research staff, and even visiting faculty from other

institutions. All have extensive federal research support and have published at least 125 articles in peer-reviewed scientific journals. The two most senior scientists (Professors A and D) have served as department heads and are routinely consulted by their universities, professional societies and national institutes on matters of policy. In short, these are unusually successful, well placed, and highly visible academic scientists. Their considerable distinction and varied commercial endeavors led us to interview them; their complex insights about relationships between the academy and industry motivated this article.

In our view, the most interesting insights to be drawn from their opinions are found in the multiple lines of agreement and dissensus that cleave across their positions on Figure 1. For instance, two scientists may concur on the importance and trajectory of a current trend in academic practice, but disagree as to its implications or the university's appropriate response. Or they may share an opinion about proper academic responses to such trends without agreeing on either the qualitative or quantitative characteristics of the phenomenon to which they respond. In addition to considering relationships across positions that share characteristics on our typology, we also consider the conflicts and agreements across the traditional old school/new school dichotomy and the two hybrid positions. By systematically examining points of tension across these diverse position, we hope to shed light on the changing nature of work in academic life science research.

Six dimensions of comparison: convergence and conflict across viewpoints.

The following sections develop the dimensions of comparison captured by the numbered lines on Figure 1. In each case, the section title represents the strongest shared attitude expressed by a pair of researchers. We expand on these shared themes with extended excerpts from

interview transcripts that highlight both the points of convergence implied by the section titles and the places where these researchers' views diverge.

1. Breakthroughs in basic science have generated commercial opportunities that now threaten the academy.

Professors A and B share the view that research breakthroughs in the life sciences have opened a new array of possibilities to academic researchers. But they also believe that the growing emphasis on commercializing basic science threatens distinctive characteristics of the university. In particular, A and B emphasize that research practices are being altered by heightened attention to patenting.

Their concerns with the academic pursuit of intellectual property echo recent trends in university research practice. Since 1980, the number of patents assigned to research universities has risen more than 700 fold (Owen-Smith 2000). In addition to a growing volume of patents, American post-secondary institutions have increasingly developed in-house technology transfer and licensing competencies. Where only a small portion of the nation's 89 research one universities had internal technology transfer offices in 1980, by 1998 all but two had created new organizational units devoted to the pursuit and management of intellectual property (AUTM 1998). Over this twenty year time period, much of the rise in university patenting has been driven by biomedical technologies (National Science Board, 2000; Ganz-Brown 1999), lending credence to Professor B's connection between increased awareness of patents, changes in life science technologies, and the rise of the biotechnology industry.

Patents are much more an issue now. Twenty years ago, the chances that basic research, no matter how beautiful and fundamental, would have recognizable commercial potential were relatively low. That's less true now. Patenting is more on everyone's radar screen. Biotechnology was not an industry 20 years ago. Now

it's a huge industry. The number of biotechnology patents has exploded for reasons that have to do as much with the science as with the patents. – *Professor B*

Likewise, Professor A's despair at the effects that proprietary research has on the tradition of academic openness mirrors arguments that pursuit of intellectual property will stifle research, either by leading scientists to delay publication (Blumenthal et al. 1986) or withhold new research tools and materials from other scientists (L. Nelson 1998; Campbell et. al. 2000).

It's anathema to me that you can find people in academic settings who won't talk about what they're doing. They can't tell you what they've found because of patents, pending patents, or applications. If you can't talk openly, it's bad. People in basic biological sciences tend to be less that way. I bet there are not many people in Ecology and Evolutionary Biology who think about patents. Whereas in biochemistry or molecular biology, where people can exploit their abilities with functional genomics and other hot areas, you may find a lot of people who lust for patentable findings and the profits that accompany them. – *Professor A*

Alongside the growth in patenting activity, increasing linkages between the fields of information technology and genetics and the development of large-scale genomic databases by commercial firms have added a new technological element to university research, requiring new sets of skills and equipment not readily available in all laboratories. The rise of for-profit firms, such as Celera, Human Genome Sciences, and Incyte, that provide access to databases comprising more than 90% of the human genome to universities, individual researchers, and other firms, has altered the trajectory and process of genetic discovery (Guterman, 2000). These new capabilities further the industrial trend toward targeted drug development, and, in so doing, more closely link commercial and basic science.

I don't know whether increased patenting is a symptom or a cause. Because of the state of development in experimental tools, microgenetics has made it much easier for any researcher to get right into the business of generating commercially useful findings. So commercial utility is much more on the radar screen of biomedical researchers. – *Professor B*

But Professor A notes a dark side of these new developments. Several analysts have underscored the effects for academic science of an increasingly commercially based selection process for federal grants (Cohen and Noll 1994), and the effects of increasingly ‘businesslike’ practices imposed on university departments with scant opportunity for successful commercialization (Hackett forthcoming; Gumport 1999). The introduction of market based criteria into university research also worries Professor A:

My group is doing old-fashioned work. We’re doing research on models. We are not doing genomics. I think if you’re those trendy modern areas, you might be seduced into biotech or a high-powered tech transfer academic career. If you’re doing our kind of work, you might see handwriting on the wall, and figure I’m better off in a small college where I’m not expected to rake in hundreds of thousands of dollars of research money. – *Professor A*

Professors A and B depart in their views when it comes to the possibilities for responding to these threats. For Professor A, commercialization stands to fundamentally alter the academic milieu, and the organization, composition, and practices of universities. Professor B, on the other hand, views propriety science as a threat primarily to individual scientific autonomy. Where Professor A laments alterations to the very fabric of academic life, Professor B expresses concerns that commercial interest in his work may lead firms to restrict research in his lab either by either defending or staking claims to intellectual property essential to his scientific program.

The differences in their responses stem from disparate views of how the academy and industry are linked. Professor B sees danger coming from outside the university, where commercial life science firms encroach on his turf and possibly limit his freedom of action.

If this university holds a patent, they’re not going to enforce it in a way that interferes with academic research, whereas a private company might. There is some incentive to disclose to the university to protect academic freedom. If someone else files a patent that conflicts with your work, that could really impair

your research. In terms of patenting genes, commercial companies that own broad rights to products can require academic researchers to have licenses. They will do that if they think the academic research generates knowledge that undermines their proprietary work.

My lab generates knowledge that could be of great value to companies. Since it is not done in a company, the knowledge could be viewed as a loss to some firms. But we want to be able to publish it. So the company might have an incentive to restrict or control our research. That's why a lot of people in the public sector are looking to undermine the ability of companies to file broad patents on large sets of genes. I'm 100% behind that effort. *—Professor B*

In contrast, Professor A's fears emphasize changes to the nature of intellectual community in the life sciences. Professor A believes commercial values are potentially corrupting of core academic commitments, undermining the academy from within. Hence, for him the real threat is internal.

I'm left with a kind of a sad, sinking feeling because I still have an old fashioned idealism about the academy. I think this ought to be an arena where all ideas are up for open debate. There should be no secrets. There should be no conflicts about one's priorities. One's priorities are to the students and the trainees, to the institution. We all get a big kick out of discovering things, but that's intertwined with our first obligation, to our trainees. I feel that that's been undermined pretty seriously.

There's a certain greedy, 'have it now' mentality that may motivate people to try to get out there and do something dramatic from which they're going to profit in a short time. Some people even choose their scholarly area in order to position themselves in that respect. *—Professor A*

Professor B believes that the university can mitigate these external threats by gaining and broadly disseminating its own intellectual property, thereby undermining corporate efforts to restrict 'basic' science investigations. His proposed solution to the external threat of intellectual property defense by firms resonates strongly with Heller and Eisenberg's (1998) concern that increased academic patenting may lead to a 'tragedy of the anti-commons' where scarce intellectual resources are underutilized because excessive patenting deters inquiry by setting up roadblocks to research.

Professor A is less sanguine about moderating these dangers to the academy. Where B believes universities can defend academic freedom from incursions by firms with whom they increasingly share an intellectual focus, A's concern with the disjunctures raised by importing commercial logics into the academy is harder to allay.

2. *The findings and audiences of basic and applied life science are increasingly similar.*

Professors B and C acknowledge that technological changes have brought industrial science and the academy much closer together. New research programs and methodologies now drive discovery efforts in both academic labs and biotech firms, producing outputs that are, in many important respects, indistinguishable.

Right now my lab could generate a huge amount of patentable material. We're doing large scale research on gene function and gene expression. A lot of our discoveries have commercial applications. I'm aware of that because there is so much contact these days with scientists in commercial firms. –*Professor B*

Only a few months after having started the company, it actually has better technology than my lab. The company is able to move much more quickly. Academics vainly perceive that they are the ultimate producers of knowledge. I think that the tables are turning. My company can produce retroviral technologies faster than my lab can. That doesn't mean that my lab can't come up with innovative things. It never really is the case that the company is fighting you for what you you're doing. It comes down to being very careful with project management and trying to make people realize that your academic goals are different from a company's goals. – *Professor C*

Nevertheless, B and C depart with respect to their assessments of the consequences of this increasingly blurred division of labor between academic and industrial life sciences. Professor B feels that industry is poaching on his terrain. He seeks to protect his autonomy by avoiding commercial entanglements and by aggressively patenting his laboratory's discoveries.

I've been offered a job where I could make ten million dollars in two years and then go back to my academic job. But it just wasn't worth it to me. I've never been interested in licensing and commercializing my own patents. I don't want to have anything to do with the process beyond filing the patents. Recently I've been a little more explicit about my own wishes in terms of licensing. But I try to stay as far from that as possible. A number of my patents are related to research methods. If a company has an exclusive license to a research method, they may find it in their best interests to limit access to that method. That is a detriment to research in general. – *Professor B*

In contrast, Professor C sees opportunities to translate academic ideas into new medical outcomes by enrolling commercial partners in the process of drug discovery and development. Instead of defending his turf, C seeks to forward his academic and commercial goals through active engagement with firms. He believes the growing overlap between science and industry opens new prospects for success in both realms and argues that collaborations between universities and industry will have positive societal benefits as they speed the discovery and development of new therapeutics and diagnostics. Far from B's concern with the negative personal consequences of commercial and academic overlap, C highlights the linkages between the personal underpinnings of his research on cancer and HIV and the increasingly close connections between industry and the academy.

To say that somebody in drug development cannot watch their ideas come to fruition, because their ideas require larger investments than the NIH is willing to put into them, is unfair. Certainly when I first brought these ideas to the NIH I was laughed at, and academics sometimes say well gee, if the NIH won't support this idea, why should we? Luckily, now my grants and ideas are given full value.

What motivates people to study a particular disease – is it money or personal health? I've had cancer twice. I've had many friends die from HIV. Look at my research, it deals with HIV and cancer. If I feel that I have an opportunity here to make a difference, and if I recognize a way to do so that isn't like a standard NIH track, then why shouldn't I do it? – *Professor C*.

Where Professor B feels that he must work to be a good scientist in spite of commercial interest in his research, Professor C holds that such interests enable him to be a much more effective and

practically engaged scientist. Survey results of funding for life science researchers also suggest that instead of a ‘crowding out’ effect in which industrial support reduces the odds of federal grant money, industrial and federal money go hand in hand. The most successful researchers generally enjoy funding from both sources (Blumenthal et. al 1996).

3. *There are distinctive reward systems for the realms of commerce and industry.*

Professors C and D are confident that commercial possibilities do not endanger academic reward systems. Neither believes the university is threatened by commerce. They agree that some degree of commercial involvement is commonplace among elite scientists. In their view, such activity advances medical research and raises human health standards. They are clear in their view that academic and commercial prizes are fundamentally different. Science is about publishing and reputation among peers, while commerce is measured by financial success. As followers of the sociology of science, we are struck by the extent to which Professors D’s comments reflect a Mertonian (1968, 1976) view of scientific rewards and motivations.

Academics is all about credit and the credit only comes to those who have peer reviewed articles. Peer acceptance signals that what they did is legitimate, and that it is right. Commerce has to do with property and stock. A patent is a simple part of the tool kit of the capitalist for doing business. Money is only of modest interest, except that academics have to live and more money is better. But most academics decided when they went into academia that they’ve given up the money.

I’m not looking for academic gain from having done commercial things. I occasionally get my name on a paper at the firm, but I spent a sabbatical there. The advice that I give them there I get back in money. So I make a very bright line division that in industry the currency is largely the currency of money and in academia the currency is largely the currency of credit. The academic business has to do with credit. Academics who really have abiding unhappiness feel they didn’t get enough credit for whatever. *Professor D.*

Professor C’s comments also reflect the separation between the academy and industry, but his description of the balancing act entailed in maintaining such a separation is more closely

related to the conception of personal commitments that Dasgupta and David (1987, 1994) use to differentiate between the academy and industry than it is to Merton's (1976) overarching scientific ethos. Dasgupta and David argue that the key distinction between academic and industrial research lies not in the actual practices of scientists and technologists, but in individuals' personal commitments to the to the reward systems and audiences associated with the 'clubs' they choose to join. "If one joins the science club, one's discoveries and inventions must be completely disclosed, whereas in the technology club such findings must not be fully revealed to the rest of the membership" (Dasgupta & David 1987:582). Likewise, C's comments suggest that the actual science being done in his lab and in his firm are essentially the same; but what differentiates them is his decisions about uses and audiences for his findings.

I don't need to be involved in the company's day-to-day operations. That is dealt with by a great management team. I drive some of the scientific decisions about technology concepts and the genetic screens we do. That's been my major involvement. It is an easy distinction. In academics we're allowed to use the technology for anything just because it interests us, but the company needs to apply it to a commercially interesting system. It has to have value. Investors don't want to see their money wasted, so there really isn't a conflict there because there's a very big difference between what is commercially interesting and what is academically interesting. What gets a paper in *Cell* won't get your product on the market and selling – *Professor C*.

Professors C and D diverge sharply on whether commercial involvement might aid scientific achievement. For Professor C, commercial involvement can provide resources in the form of human capital, equipment, and access to proprietary information that enhances his scientific inquiries. In short, he believes good science is independent of institutional location, and his commercially motivated work contributes to his academic research program.

The environment here is one of technology development. Maybe it's that people are allowed to do what they want and that we aren't tied down to the old style, academics for academics only. Commercial success can shift the balance of

power. It helps determine how much money you have and influences how many post docs you can hire and how much space you can fund. That can feedback into better science.

I don't list companies or patents in my NIH grants. People may know about them. My interaction with my company enables me to feel more confident in what I'm stating in my grants. That's useful. Having collaborations with companies has helped me. The granting system is a weird operation. It mixes how good the idea is with how much people respect you. Respect means how many times have they seen your name in the journals, or on the major speaking symposia, and how much they have used your reagents or information – *Professor C*

The picture Professor C paints is one where advantage accumulates in the manner suggested by Merton's (1968) invocation of the Matthew Effect – “To those who have, more shall be given.” But that advantage now develops by mobilizing resources across the once separate academic and industrial realms (Owen-Smith 2000). In a world where firms and universities increasingly represent a common community, the boundary between the two becomes more symbolic than actual, and visibility in one arena can contribute to success in the other.

Beyond personal accumulative advantage, C's comments highlight several salient features of scientific work in the field of biotechnology. Rivalry in this field increasingly occurs across networks rather than between individual firms, as races to discover and commercialize new knowledge encompass university, government, and industry researchers (Powell et. al. 1999). Indeed, there is evidence that ties to elite partners in R&D networks enhance firms' chances of winning such knowledge races (Koput and Powell 2000). C's close ties to a biotech firm map onto the findings of Zucker and colleagues who demonstrate that new firms in this industry depend on linkages to local universities (Feldman and Audretsch 1998; Zucker, Darby and Brewer 1998). Moreover, firms' successes have been linked to the academic status of their scientific advisory boards (Zucker and Darby 1996). Clearly, Professor C's view that academic

and industrial success are two sides of the same street reflects more than idiosyncratic experience.

In contrast, Professor D argues that far from forwarding an academic career, some types of publicity, be they popular or industrial, will damage a scientist's chance to advance in the 'unforgiving' academic community. To this scientist, there is a sharp divide between scientific and commercial avenues to success, and the academic route has clear priority. In his view, the academy is the ultimate arbiter of veracity and quality. Academic success may translate into commercial opportunity, but the reverse is not viable as commercial attainments are not commensurate with academic reputation. For Professor D, academic accomplishment can generate economic activity, but the traffic is only one way and too much concern with the world of commerce can limit academic attainments. Reflecting the contradictory position he occupies, Professor D's description of the null or even negative relationship between academic prestige and commercial success opens with the statement that he lists patents on his curriculum vitae.

Some people, including me, put their patents on their CVs, but in the academic community they are wholly discounted because they are not peer reviewed. Our community is very unforgiving. Only one thing counts, the rest doesn't matter. In fact, even a guy who is extremely famous, like Carl Sagan, was never elected to the academy because he was a popularizer, he hadn't published enough. Jonas Salk is the same story in a way because the serious work was done by somebody else. Salk didn't get a Nobel prize, Enders did. Salk did the industrial piece, and Enders did the scientific piece. That's why everyone is indifferent about patents in the academic community. They can't even be used as an argument for having discovered something. -- *Professor D*

4. *In science, truth and beauty are orthogonal to profit.*

Professors D and A share the 'old school' view that the academy is a distinctive institution. In their views, the academy is concerned fundamentally with the pursuit and discovery of new knowledge. For Professor D, a strong separation between the academy and

industry is based on peer recognition, community judgments of legitimacy and veracity, and sustained publication in high-profile journals. For A, the distinction between the academy and industry hinges on participants' commitments to open debate. Even though they agree on the priority of academic accomplishments, they part company on whether these standards are in jeopardy.

Professor D sees little danger from commercial involvement because academic rewards are apportioned independently of commercial success. Central to this view is the proposition that patenting and commercial activities are largely independent of the scientific value of discoveries. Indeed, following Dasgupta and David (1994) or Packer and Webster (1996), Professor D argues that the realms Professors B and C view as increasingly similar represent distinct audiences, outcomes, and accomplishments.

Patents are objects of capitalistic commerce, they are not objects of scientific truth. Patents are judged by government-employed post-docs. Imagine an academic situation where the level of review is here [hand held low] and the science is here [hand held high], that's the patent office. Everybody knows that. So whereas people will jockey for position on a paper, they never do that for patents. Some scientists don't even care to proofread the damn things. –
Professor D

Professor A agrees that academic status takes precedence over commercial achievement, but worries that the features that make university-based science unique may fall victim to the commitments and lifestyles of the commercial realm. In essence, he is concerned with the very contradictions inherent in the positions held by Professors D and B, whose hybrid locations lead them to rely on individual commitments to academic values to maintain a distinctive academic realm in the face of either commercial encroachment or industrial involvement. Where Professor D holds that academics do not care about the world of commerce but can enter it with little

compromise, Professor A worries that few academics can resist the temptation of economic attainment and that the pushes and pulls of such endeavors will endanger both academic life and the university as talented potential faculty are lured away from the university.

We now have competition between biotech companies and the academy for the same people. So it is not only that faculty are living conflicted lives, there is also a hemorrhage of talent from established faculty and from the pipeline. Industry is skimming off really outstanding people. They tend to be the very best people, the ones who you'd like to see become research leaders at universities, and they're gone. It is so bad that in some areas now you don't even see any qualified graduate students, because they're skimmed off as undergraduates. These forces are changing life within the university and the quality and number of people coming in. These opportunities are changing the career choices people make.

Some people get so turned off by what they experience in the modern research university that they decide they want academic careers at little colleges, where there is a simpler environment. They don't want to do what I do. They don't want to be in a big research environment with grants to sweat about. I've seen a fantastic growth in the amount of interest among in careers in independent four-year colleges. This is not just people who couldn't cut it. These are really good people who are making a positive decision that they don't want any part of this. They have a kind of quiet passion. I think in most fields you'll see people who have that kind of a quiet scholarly passion. They used to be a common breed on campuses, but I think they are getting rarer. —*Professor A.*

A recent discussion in the *Chronicle of Higher Education* on the revamping of graduate education echoes Professor A's comments. The eminent biologist Leroy Hood comments that "When I was a graduate student, there was something really wrong with you if you went into industry. What I see now is some of the very best students are going into industry. They see industry as more compatible with a reasonable life" (Manger 2000). Hood observes some of the same trends highlighted by Professor A. But Hood, who in 1999 left an endowed chair in molecular biotechnology at the University of Washington to head a new institute, the Institute for Systems Biology, sees few negative implications. Professor A fears a 'hemorrhage' of talent from the academy. Instead, Hood's statement is more in line with Professor C's emphasis on the

increasingly central role that industry plays in life science inquiry and the view that industrially-based scientists may actually have an advantage in races to discover new findings.

5. *The criteria for success in science are being redefined.*

Despite the fact that they are separated on both dimensions of Figure 1, Professors A and C think that the world of the life sciences is changing. Both faculty believe the increasing overlap between the reward systems of academia and industry affords accelerated advantage to scientists who succeed in both realms. At base, these two researchers concur that the paths to academic success, and the standards by which achievement is measured, have been altered.

There are different ways you can have advantage. You can have more space, have more grant money, or have more hands working with you. People who get involved in biotech as founders or partners in companies end up with all those advantages. They end up with money in addition to their academic grants. This development is part of that blurring of the line between the two sides of the lab bench. These scientists end up with extra hands. They end up privy to ideas and information that other people can't get because of the proprietary nature of the work done in firms. That is another very important kind of advantage. This trend creates huge differentials between the little operator who has to get by on limited grant money with very few co-workers and somebody who presides over a juggernaut. – *Professor A*

Older faculty come from a different school. They come from a time when it was either academics or industry, and industry was money grubbing. They came from a time when producing knowledge was an end in itself. They come from a time when there weren't the pressures put on us now to justify why the taxpayer is paying our bills. Look at the kinds of grants that are coming out of the NIH these days. Look at the way everything is moving in science. The common comment is, that is interesting but what does it give the taxpayer. We are the taxpayer's servant. The ivory tower academic has got to realize that it's very selfish to say you owe me the money so I can go out there and do what I want and you have no say over how your money is being spent. – *Professor C*

Both A and C also share the belief that academic career trajectories are changing with the new, overlapping, reward system. But they differ in the degree to which they perceive these changes

as potentially dangerous. For Professor C, increasing overlap yields opportunities to enroll multiple groups in the pursuit of good science, regardless of their organizational locations. In contrast, Professor A views the potential loss of the academy's position as a prestigious and untainted location for disinterested inquiry as a danger. To a certain extent, then, C's view of the world of academic entrepreneurialism represents the belief that individual scientists can have their cake and eat it too. A agrees, but notes the possibility of increasing structural inequities within and across universities, and fears the trend toward institutional prioritization of high-profile, commercially active scientific fields at the expense of intellectual diversity.

There is a scientist named Leroy Hood, who is a legend. He was a professor at Cal Tech and then he was literally bought by the University of Washington.⁵ His lab has about 200 people in it. He's a molecular biologist, biotechnology person. In a Cal Tech annual report most people list their grant support on a few lines. His list of support took three pages. He's a good scientist, a force to be reckoned with. But he's just a fantastic entrepreneur. He represents a whole new model of what it might be like to be a successful biotechnology kind of professor. He certainly has got his hands in lots of biotech enterprises and he's a great example of a 'have.'

I have a feeling that if we don't get with the new program, and I'm not entirely happy about getting with the program, we're going to be perceived as being less important. In biomedical science, there is a very widespread feeling that the higher quality you are, the more you're going to be raking in, the more patents you'll have, and the more companies you'll be associated with. With the university administration, I sense that the more money you can bring in, the more likely you are to get infrastructure, encouragement, and lines. There is a big reorganization under way such that traditional fields, small low funded fields that endow the institution with great diversity, are going by the wayside. What you're going to wind up with are big juggernauts of work in a few areas like functional genomics. – *Professor A*

⁵ When Leroy Hood left the University of Washington to found and direct a private research institute bankrolled in part by pharmaceutical and biotech companies, Washington's president expressed confidence that Hood would not be 'lost' to the academic community and his hope that faculty would continue to work with Hood's institute. Since that time, several senior faculty have left the University of Washington to join Hood's institute on a full time basis. One of those scientists, Ger van den Engh, noted that one reason for leaving the academy was the need to commercialize findings "We need to commercialize what we do, to make it available to other laboratories, and that is . . . just not in the mandate of universities" (Gutterman and Heller 2000: A11).

6. *Scientific values are resilient in the face of commercial gain.*

Professors D and B stand in hybrid positions united the belief that the values and practices of academic scientists can be sustained in the face of commercial involvement. For both these scientists, pursuing commercial endeavors -- be they patents, start-ups, or consulting arrangements -- are corrupting only if individual scientists allow themselves to become enmeshed in conflicts of interest. These two highly committed academic scientists, both of whom commercialize their research findings, focus on individual choices and loyalties, and highlight the need for researchers to police one another and their institutions to maintain the 'purity' of university science in the face of increasing possibilities for conflicts of commitment.

Good basic researchers constantly have to be resourceful, innovative and risk-taking, the sorts of things you associate with entrepreneurs. The difference is that they are driven by altruism, curiosity, and an adventurous spirit, not the chance of making big bucks. – *Professor B.*

Professor X's reputation in biotechnology may be very high. But don't bet on his scientific reputation because instead of paying attention to his research and his students he's paying attention to the licensing office. He is an example of the kind of conflict of commitment that the university tolerates. I'm not accusing him of doing anything wrong, but he works for Biotech-Z. – *Professor D*

These two scientists share the belief that the behaviors and attitudes characteristic of new school faculty members represent choices to abandon traditional academic values. Such choices, they feel, raise conflicts within the university and call into question the commitments of academic scientists to students and disinterested inquiry. The divide over appropriate levels of industrial involvement, reflected in diverse views about the proper university industry admixture, and over definitions of conflict of commitment is the sharpest we encountered. The conflicts surrounding these issues are clearest in discussions of commercialization's effects on the teaching/mentoring

role. Note both Professor D and Professor A's strong concerns with more new school faculty's commitments to students and trainees.

Interestingly, Professor C, our ideal new school scientist, is the most open in discussing his commercial engagement with graduate students and post-docs, encouraging them to take law school and business courses on intellectual property and contracts, showing them the ropes concerning the expectations of industry, and sharing both credit and profits on research where they collaborate. He is remarkably transparent about his activities and egalitarian with his associates. We found this openness quite interesting, as many hybrid and old school faculty were much more reluctant to discuss their entrepreneurial activities. On the other hand, for Professor A, Professor C's engagement model, reflecting academic plus commercial training, is precisely what worries him the most as it may lead talented students to abandon the academy all together or further weaken 'traditional' values in those who do pursue faculty careers.

The individualist focus that B and D maintain suggests that the university and its faculty must be policed if conflicts are to be avoided. For Professor D, the possibility of a tainted academy arises from academic incompetence in the industrial realm, an inability born of the clear distinction between academic and commercial reward systems he shares with Professor C.

The patents a typical professor applies for are ego patents. The professor thinks it's going to cure cancer, yadda yadda yadda. He thinks he's going to get rich, and the university thinks it is going to get rich to the point where the university closes both eyes to conflicts of interest.. Well, that's not competent. Having your name on a patent, even for something very important, is meaningless. Whenever I do it, and I'm not alone, I let the commercial organization deal with the problem. –
Professor D.

In contrast, Professor B perceives a need to oversee university patent licensing, not because of the institution's incompetence, but because of a fear that commercially oriented academics,

savvy in the overlapping realms of academia and industry, may take advantage of their privileged positions and ‘snooker’ the university into actions that restrict the ability of university patents to defend against threats to academic freedom.

The university has screwed up by making exclusive licensing arrangements. In one case, I mentioned to the associates that I felt they were getting snookered by the licensee, who happened to be my graduate student. I knew exactly what he was doing, and I said I would look very closely at the license terms. I wanted to stay out of it because I had a conflict of interest. They granted an exclusive license and they lived to regret it because the technology turned out to be very valuable. The exclusive license generated a lot of resentment, flack, and complaints from a company that was angry because the solicitation letter was too nebulous. They felt the technology wasn’t adequately described. The letter was written by the student who wanted the license and it was intentionally obscure. In my view, it is, a good idea for tech transfer to start out with a very strong bias against exclusively licensing any technology that has broad utilities because such licenses impede the dissemination of the technology. – *Professor B.*

Professors B and D share the belief that commercial endeavors are not necessarily conflictual, but they are risky. Despite their separation on both dimensions of Figure 1, then, these scientists concur that dangers inherent in commercialization are best addressed at the individual level. In spite of these similarities, they differ in their beliefs about the permeability of the university-industry boundary, and the types of danger such overlaps present to academic science. Born of his belief that there are few practical distinctions between academic and commercial research, B’s concern with commercial encroachment on his laboratory leads him to desire greater commercial involvement and oversight by the university. In contrast, D’s sharp distinction between the realms leads him to believe that such organizational involvement is unnecessary and perhaps even detrimental, as universities lack the relevant competencies in the commercial realm.

Implications: Fault lines and bridges

The transformations underway in the academy are the result of dramatic shifts in the nature of scientific knowledge and the growing salience of knowledge networks and spillovers in economic activity. Developments in the academy have been both causes and consequences of the growth of new technology-based industries. The bulk of university patenting in the last ten years has been driven by biomedical patents that depend, for commercial success, upon the biotech industry (Ganz-Brown 1998). Clearly, upheavals in the academy reflect larger changes in the economy and the relationship between academic and commercial R&D. These shifting grounds change the landscape for faculty.

This new landscape raises questions about the role of the university in coming years. Will universities increase in importance as “engines of economic development” (Feller 1990)? Will a university blunder so profoundly in its ventures into the marketplace that the entire enterprise loses legitimacy? Or will universities that keep the tensions and controversies alive, as subjects of active debate, thrive? In the latter scenario, university-level success would be dependent on the creation of an institutional environment that is simultaneously supportive of both basic and commercial science activities. Consequently, success and continued viability would entail both commercial and academic attainment, and the ability to mobilize and support diverse types of faculty.

We focus on potential alliances and quarrels because the changes at work in the life sciences raise new challenges for universities that hope to thrive in a world where commercial outcomes offer new possibilities and pitfalls for academic institutions. Owen-Smith’s (2000, forthcoming) research on university patenting suggests that the reward structures of science and

commerce increasingly overlap, creating a situation where advantage accrues to institutions not only within each arena but also across them (see also Narin et. al. 1997). The picture is one where simultaneous success in both the commercial and the academic realms has a multiplier effect on rewards, catapulting those universities that succeed at both to higher levels of accomplishment than those that are successful in only one field.

Our analyses suggest that a strong outcome of increasing academic concern with research commercialization is the appearance of new fault lines among faculty, between faculty and students and even between scientists' interests and those of their universities. We argue that the increasing life science commercialization is driven by a mix of new opportunities for funding, changing mandates for universities, and novel research technologies that bring basic research and product development into much closer contact. The rise of patenting and commercially motivated technology transfer on U.S. campuses stands to alter faculty work practices, relationships and the criteria by which success is determined and rewards are allocated. Through close analysis of four interviews with faculty who typify a range of academic responses to commercialism, we demonstrate the emergence of several key fault lines in the responses of life sciences faculty to commercial opportunity.

Consider the two dimensions that comprise Figure 1, beliefs about university-industry separation and concerns about commercial threats to the academy. The scientists we interviewed differ widely in their perceptions of appropriate faculty behavior, legitimate responses to a more commercially-driven academic world, concerns about students and the university's teaching function, and worries for the academy's future. The faculty's passionately held and sometimes diametrically opposed positions raise the spectre not only of increased conflict between faculty

and their institutions, but also of increasingly dysfunctional outcomes for universities as schools and departments splinter on issues involving appropriate policies regarding commercialization. At the same time, new school faculty are seeking less constrained positions from which to pursue basic entrepreneurial science and commercial development.

Scientists separated on one or (especially) both of these dimensions manifest widely disparate concerns and attitudes regarding research commercialization. The points of departure we highlight above represent potential sources of conflict among faculty who work in the same universities and often the same departments. The existence of these debates suggests that faculty may fracture along these lines, creating schools and departments where internal faculty conflicts can limit collaboration and hinder educational efforts. In a world where life science research is increasingly defined by close collaborations across diverse research areas, scarce students, and winner-take-all reward structures, such conflicts may limit a university's ability to compete in both the academic and commercial arenas.

At the same time, the complex transformations we examine necessitate multifaceted responses on the part of faculty. We call the most complicated of these responses hybrid positions to acknowledge that the scientists who hold them mix attitudes characteristic of both the old and the new school. These hybrid positions manifest internal contradictions -- such as reluctant entrepreneurs desire to defend academic autonomy from commercial encroachment by making the university a commercial player in its own right -- that create the potential for unexpected bridges across conflicting viewpoints.

The six points of similarity among the faculty types presented in Figure 1 can present opportunities for building bridges that could potentially unite conflicting positions. Following the paths laid out on Figure 1, the points of agreement we find are:

1. Breakthroughs in basic science have generated commercial opportunities that now threaten the academy.
2. The findings and audiences of basic and applied life science are increasingly similar.
3. There are distinctive reward systems for the realms of commerce and industry.
4. In science, truth and beauty are orthogonal to profit
5. The criteria for success are being redefined
6. Scientific values are resilient in the face of commercial gain.

The first point, for example, represents a shared belief, spanning the old school and the reluctant entrepreneurs, that threats to the academy are largely the result of faculty's own activities. Consequently, these issues should be dealt with using mechanisms internal to the institution. Where faculty who hold these positions may disagree strongly on the extent to which the university should be involved in industrial activities, their shared belief that such involvements represent obstacles that are best mitigated internally may enable coalitions to form in spite of the differences.

The last two points of convergence span the broadest chasms. These views constitute apparent agreement across faculty who are otherwise separated on both of the key dimensions we identify. Were it not for the contradictory character of these hybrid positions, old school and new school faculty and the two mixed positions would share little in common. Instead, we find engaged traditionalists and reluctant entrepreneurs united in the view that the values characteristic of academic science can be maintained in the face of commercial endeavors. Moreover, these scientists agree that the maintenance of academic values is an individual responsibility. Further, this shared viewpoint leads both groups of scientists to agree that faculty

should police themselves *and* their universities to avoid potentially damaging conflicts of interest and commitment. These common underpinnings and tactical sensibilities are a potentially strong basis for coalition building.

On the other hand, debates about graduate and post-doctoral training may produce further discord. Unlike their elders who are adapting secure careers to changes at least partially of their own making, neophyte and junior scientists must accommodate the tensions and discrepancies inherent in attempts to successfully pursue 'hybrid' careers that encompass both academic and industrial components. Pursuing such careers in the academy can be a risky business as the faculty conflicts we identify suggest. Indeed, for junior scientists, new school or hybrid career success may come at the price of conflict with senior faculty whose norms of appropriate behavior depend on the idea that academic and commercial reward systems are distinct. Indeed, if the old and new school distinctions we highlight here map onto age or cohort distinctions (e.g. old school faculty are senior while new school scientists are junior), then in addition to concerns about personal outcomes, young scientists may worry that their seniors will block new findings, hindering innovation. Though, as Stephan (1996:1217) notes, this worry is at least as old as Max Planck.

The numerous fault lines apparent across life science faculty may swallow junior scientists who attempt to match early career development to the exigencies of a world where commercial and academic science are blending. Our research suggests that such chasms can be bridged by virtue of linkages across contradictory positions, but, as Professor C's early frustration with the granting system and with 'ivory tower' academics suggests, building such bridges may be a difficult task. If this is the case, then Professor A's fears of a hemorrhage out

of the university may be even more justified as junior scientists tire of bridging chasms with their senior colleagues and opt instead for careers in firms or in the 'simpler' teaching based environment of four year colleges. As the grounds that support university-based life science research shift, academic careers may be less appealing to scientists whose work increasingly spans firms and university laboratories.

Where universities may be dominated by complex relationships among different types of faculty, industry may appear less conflictual. The new knowledge-intensive private settings may draw more scientists to pursue 'academic' research careers in corporations and institutes (Smith-Doerr 1999). This trend suggests that cutting-edge life science research may increasingly be situated in industry or hybrid organizations, while the teaching function remains university based. Alternatively, early stage academic careers may come to serve as launch pads for entrepreneurs who have little interest in remaining within the academy, but instead use university positions to locate and develop commercializable property. Witness Professor B's graduate student, who licensed a technology from the institution where he was trained in order to spin-off a firm. As faculty understandings of careers and accomplishments shift, even the meaning of academic affiliation stands to be altered.

Our interviews suggest that these economic, institutional, and scientific transformations are changing the meanings that academics attach to scientific careers. The terms of success and the organizational location of high impact research have changed. Today, it is possible to do serious basic science work in both academic and industry settings. Consequently, more traditionally oriented faculty face a tension in their teaching and mentoring roles. These professors must decide how to prepare students for careers in a world where commercial

involvement is likely to be the norm without undermining the core academic values that they hold dear. At the other extreme, commercially-engaged faculty, particularly those we classify as new school, face the challenge of educating students to excel in the complex world they inhabit while avoiding conflicts of commitment and the stigma associated with pursuing science for commercial gain. Our interviews suggest the negative implications of being 'in it only for the money' remain salient for academic life scientists. Across universities, growing attention to patenting and research commercialization are challenging researchers' core values, remaking the standards of success they have lived by, and, ultimately, requiring them to redefine their identities as scientists and academics. The shifts brought on by commercialization, then, have far reaching ramifications for the organizational of universities, scientists professional and personal work practices, and even individual accounts of identity and appropriate behavior.

In addition to their impacts on the university and the professorate, the trends we highlight have broader implications for science policy. Dasgupta and David (1994) argue that the 'republics' of science and technology exist in a fragile equilibrium. The funding structures and norms of information disclosure characteristic of science are, in this view, designed to promote the growth of a stock of basic knowledge. In contrast, the arrangements typifying the republic of technology are designed to promote the appropriation of rents from innovation. The two realms, then, necessarily exist in an uneasy balance.

If science comes to dominate, then rents from technology decline, eventually limiting investments in basic R&D. If, on the other hand, technology dominates, bringing with it a proprietary approach to information disclosure, then rents are maximized, but secrecy constrains the growth of basic science knowledge. At the same time, technologists erode the current store of

basic knowledge, which is not replenished, leading eventually to limited innovation and minimal rents. Under such a model, maintaining a ‘proper’ balance between scientific discovery and commercial application is the key charge of science and technology policy.

Like some of the scientists we interviewed, Dasgupta and David (1994) espouse a sharp view of the boundary between science and industry. Hence, new school entrepreneurial activities give them pause, as such behaviors introduce proprietary disclosure norms and private funding sources to the ‘open’ university community. In terms of the equilibrium model of science and technology, the dual orientation characteristic of Professor C and his new school colleagues is dangerous precisely because it blurs the very distinctions that enable policy makers and theorists to maintain, or even discuss, a balance between the realms.

We agree that the commercial and academic realms must be balanced to enable both innovation and value generation. We see the balance less in either/or terms, however. We note that secrecy in the academy is not associated solely with commercial interests; races to establish purely scientific priority have long been cutthroat. Findings from a recent survey of medical faculty demonstrate that across levels of commercial engagement, the most prolific and high profile scientists are the most likely to suffer from data withholding (Campbell et. al. 2000). Clearly, the degree of open communication across the realms is more a continuum than a dichotomy.

On the other hand, we are struck by changes in the realm of technology. Note that Professor C, one of the most proprietary scientists we interviewed, is by far the most transparent in his research practices, sharing strategies for success and rewards from commercial activities with lower-level university associates. Elsewhere, we have argued that the life science industry

has played an increasingly important role in generating basic science discoveries (Powell & Owen-Smith 1998). Note, for example, the discovery of polymerase chain reaction (PCR) methods by an ‘industrial’ scientist at Cetus (Rabinow 1996), and the extensive role played by commercial organizations in mapping the human genome.

Consequently, we share Dasgupta and David’s (1987, 1994) view that a durable balance between science and technology is necessary. But we suspect that recent changes in academic and industrial practice are so far reaching that striking such a balance is more a matter of managing the simultaneous and overlapping involvements of scientists and organizations than of differentially weighting the separate ends of a balance scale. Most of the scientists we interviewed shared the general opinion that, for good or ill, the warrants, activities, and standards for success in basic research are changing. This feeling is most apparent in the points of convergence and conflict across Professor A and Professor C, the old and new school faculty, but the more individualist responses of Professors’ D and B also reflect some aspects of the increasing interpenetration of science and technology.

We argue that the increasingly blurry boundaries between proprietary and scientific approaches to information disclosure have led to a situation where individual scientists, universities, and potentially firms must compete in both the academic and the commercial realm in order to achieve. If there is, as Professor A fears, a hemorrhage of talent from the academy, then firms that manage to internally balance commercial and academic outputs may be differentially advantaged in the competition for productive new school scientists who, like Leroy Hood and colleagues, may leave the ‘restrictive’ university for more flexible employment in commercial firms. The need for individuals and organizations to simultaneously pursue

potentially rivalrous activities suggests a new sense of what it means to balance science and technology. Maintaining the necessary equilibrium in the complex world that our informants describe may be less a matter of tinkering with funding streams and policies and differently privileging the concerns of separate scientific and technological communities than of reworking arrangements and practices internal to organizations that must increasingly span the republics of science and technology.

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