The Oncomouse That Roared: Hybrid Exchange Strategies as a Source of Distinction at the Boundary of Overlapping Institutions[1]

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Conventional wisdom suggests that when institutional logics overlap, the production of hybrids signifies collapse, blending, or easy coexistence. The author provides an alternative interpretation: hybrids can maintain a distinctive boundary and can emerge from contestation, not coexistence. This alternative interpretation is grounded in an analysis of a critical moment at the academic-commercial boundary: the enforcement of patents to a key technology on academic geneticists. In their reaction to commercial encroachment, skilled actors (scientists) took the resources of the commercial logic and transformed their meaning to establish hybrid strategies that preserved the distinctive institutions. Thus, hybrids must be reconsidered as emerging from conflict and produced through boundary work to maintain the distinction and resilience of logics.

Institutions with overlapping boundaries shape much of contemporary social life, forming a complex zone where action is governed by multiple and varied logics (Friedland and Alford 1991). By combining a wealth

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of tools for social interaction with a range of material and symbolic resources, individuals at these boundary zones can implement hybrid strategies of action (Swidler 1986; Haveman and Rao 2006). However, when different institutional logics overlap, conflict over interpretations of behavior, responsibilities, and meaning arise; this places a strain on the organizations and the individuals caught within the shared boundaries. For example, at the science-market boundary, Louis Pasteur was widely criticized and personally conflicted as he pursued hybrid strategies, moving back and forth between his "pure" scientific work and the more applied, commercial problems French industry called on him to solve (Geison 1995). At the family-work boundary, mothers are conflicted as they seek to create hybrid exchanges that balance working responsibilities with the demands of family life (Zelizer 2005). Whenever physicians are visited by pharmaceutical representatives, they are caught and potentially conflicted at the boundary of the market and their profession (McKinney et al. 1990; Wanza 2000)

In studying hybrid strategies of action where institutions overlap, this article aims to sharpen our understanding of these hybrid zones by examining the mechanisms shaping the hybrid boundary (Schneiberg and Soule 2005; Lounsbury 2007; Schneiberg 2007) and the link between the boundary's hybrid properties and the mechanisms at work (Lamont and Molnar 2002). It resolves the conflict among scholarly observers who have made at least three different arguments about hybrids, the mechanisms producing them, and their implications for institutional logics. The first is often referred to as the "hostile worlds" perspective: these social theorists argue that hybrids are produced as a result of the invasion of one logic by another. Producing hybrids is a step toward domination, along with collapse of the other institution (Kuttner 1997). Theorists in this line warn of blending, especially with respect to the typically uneasy marriage between the market logic and other previously "protected" arenas of social action, which they view as a step toward commodification. Even when scholarship is less normative, for example, in the case of the shift from a professional to a market logic in publishing (Powell 1985; Thornton and Ocasio 1999; Thornton 2002), these studies are constructed around the notion that boundaries characterized by hybrids are indicative of a logic in the process of collapse and capture (Haveman and Rao 2006).

Another stream of literature invokes a perspective from organizational ecology: hybrids emerge through blending mechanisms that reduce the distinction between previously different (and potentially conflicting) institutions (Hannan and Freeman 1989). Unlike the hostile worlds view, this "blended worlds" perspective is not normative in its formulation. For example, the hybrid cuisines developed by French chefs and described by Rao and his coauthors capture a (culinary) blending of ingredients

from two previously distinctive logics (culinary traditions; Rao et al. 2003, 2005). Likewise, the transformation of thrifts arose through the blending of different basic plans, ultimately eliminating the norms of mutuality (Haveman and Rao 2006), while in Eastern Europe, Stark (1996) has illustrated the power of "hybrid mixtures of public ownership and private initiative" that characterized recombinant "mixed property forms" that transgress traditional property boundaries but allow actors intent on survival in ambiguous times when boundaries are blurring to hedge their bets. In this view, hybrids are consistent with a loss of distinction at institutional boundaries.

These two perspectives explain cases in which logics have collapsed and blurred. However, they fail to account for the many instances where, even in the presence of hybrids, boundaries remain resilient and logics distinct. A third line of research highlights this rich potential for hybrid strategies of action at overlapping boundaries without apparent collapse or blending of logics (Lamont and Molnar 2002)—a form of "coexisting worlds." The approach focuses on complex exchanges that combine different material and cultural resources to create productive new outcomes. The coexisting worlds view does not require that the exchanges supporting coexistence be internally consistent; museum curators arguing for both conservation and education illustrate a hybrid that allows for professional rhetoric and administrative pragmatism (DiMaggio 1991). Nor does it necessarily call for careful coordination. In his analysis of physicists, Galison describes the boundary between different experimental subcultures as a trading zone, providing scientists with a setting for hybrid exchanges even when the significance of the objects traded is different for the two traders (Galison 1997). While the coexisting worlds approach helps explain the surprising stability of logics in the presence of hybrid exchanges, its emphasis on apparently unproblematic combinations of multiple, often conflicting, resources belies the tension in these complex zones (Rao 1998; Orren and Skowronek 1999; Schneiberg and Soule 2005). By ignoring the dynamics surrounding the initiation of these hybrids and the tension between various meanings produced in any particular exchange, the coexisting worlds view fails to directly tackle the meaning of hybrid strategies for the nature of overlapping logics.

None of these three interpretations of hybrids adequately accounts for the hybrid strategies that characterize the overlapping boundary zone between the logic of commerce and the logic of science (Dasgupta and David 1994), a situation that raises doubts about the completeness of these three alternatives more generally: the boundary has long been a place of contestation by scholars of science as well as by scientists themselves, who make their claim for the distinctiveness and institutional autonomy of science (Gieryn 1985, 1995, 1999, p. 23) while training students

for industrial careers, receiving industry sponsorship, and serving as consultants to industry (Furman and MacGarvie 2007). Today, the boundary debate is animated by the growing role of entrepreneurship on campus, the founding of entrepreneurial companies, academic participation on scientific advisory boards of firms, and the spread of commercial contracts and licensing into academia (Etzkowitz 1998; Kleinman 2003; Stuart and Ding 2006). The most widespread symbol of the encroachment of the commercial logic into academia is the rise of patenting by faculty members (Owen-Smith and Powell 2001; Azoulay, Ding, and Stuart 2007). Mirroring the broader institutional debates, the three traditional approaches to hybrids understand and interpret the role of patents in distinctly different (and contradictory) ways.

The hostile worlds interpretation argues that patenting represents invasion by the commercial market, presaging the wholesale collapse of the logic of academic science. This perspective, espoused most vocally by scholars of ethics, public policy, and the law, claims that academic science is fragile and that commercial strategies have deeply encroached on academia. As a result, the norms and values of academia are undermined, leaving the boundary blurred and subject to imminent collapse (Krimsky et al. 1996; Resnik 1998a, 1998b; Krimsky 2003). Proponents of this view look at the norms and strategies of academic and commercial science, conclude that they are incompatible, and then project that adoption of market strategies such as patenting and licensing is causing the institutional logic of academic science to collapse (Broad and Wade 1993; Bowie 1994; Ziman 1996). Failing to recognize that academic science has never stood in isolation from the market, this line of scholarship has largely focused on the impact of private funding and views patents as contributing to weakened objectivity and secrecy (Bowie 1994; Munthe and Welin 1996; Blumenthal 1997; Campbell et al. 2000, 2002). A line of argument based on legal scholarship reaches similar conclusions (Heller and Eisenberg 1998), predicting that with the rise in academic patenting, the "intellectual commons" will collapse and be replaced by a landscape of patent rights subject to the increased transaction costs of accessing knowledge (Heller 1998). Such scholars argue that as patented knowledge becomes more costly to access by other researchers (academic or industrial), the fragile equilibrium of the academic logic will be undermined (Gambardella and Hall 2006), and a shift to a commercial logic will follow (March and Olsen 1989).

The blended worlds view argues that hybrid strategies blur the boundary between academic and commercial science, leading to seamless networks of relationships between the two. Proponents claim that a blended hybrid is emerging, rendering the academic-industry boundary less salient (Powell et al. 1996). Two forces have purportedly been at work in pro-

ducing this effect. First, by elaborating a set of complex commercial governance processes and commercial ownership rights, a dense and interpenetrating network developed between scientists on both sides (Zucker, Darby, and Brewer 1998; Edwards, Murray, and Yu. 2003). As these exchanges become durable and predictable, formal ties have become the dominant feature of the life sciences (Owen-Smith et al. 2002; Owen-Smith and Powell 2003; Powell et al. 2004). The second is that a hybrid evaluative regime—what Owen-Smith (2003) refers to as a hybrid logic—has emerged, as universities rely on both commercial and academic rewards to produce their status ordering. Under the new hybrid, achievement in one realm is dependent upon success in the other, and those universities that are successful in patenting are also more successful in publishing (Owen-Smith 2003). The converse is also true, with life science firms that publish and effectively build sophisticated networks to academics achieving greater levels of success (Henderson and Cockburn 1994; Owen-Smith and Powell 2004). Some scholars argue that these two elements have rendered the entire (life) science community into a seamless web of relationships, lowering the distinction between academic and commercial science, with, presumably, an eventual merging of the two logics.

The coexisting worlds perspective argues that, notwithstanding hybrid exchanges at the boundary and within academia, nothing has changed: the academic logic remains intact; patents are simply being combined with publications as the mechanism of knowledge transfer (Agrawal and Henderson 2002; Thursby and Thursby 2003), signifying easy coexistence. This line of argument is supported by survey work: academic scientists answer that they pay little or no heed to patents, are unaware of what is patented, and do not consider them when they pursue their research projects—all the while patenting at ever increasing rates (Walsh et al. 2003). Hybrids seemingly provide a convenient but uncontroversial mechanism to move knowledge across the academic-commercial boundary using a richer variety of approaches (Murray 2004) that are potentially more efficient than traditional mechanisms (Kieff 2005; Kieff and Paredes 2006). While the coexisting worlds model argues that the boundary is a hybrid of publications, patents, contracts, and informal understandings, it suggests that no processes are at work reshaping the underlying institutional logics, and neither blending nor collapse lie anywhere in sight.

How can we reconcile these different interpretations of hybrids at one important institutional boundary? The disagreement suggests that our understanding of the mechanisms that give rise to hybrids and what hybrids signify for an institutional boundary remains to be fully developed. The apparent resilience of the academic logic suggests that, contrary to much of the institutional literature about boundaries (Lamont and Molnar 2002), the existence of a boundary with hybrid properties does

not seem to guarantee that mechanisms of collapse or blending are at work. However, the controversy that continues to rage over the notion that money taints and profits corrupt academia illustrates the limitations to the idea of easy coexistence.

The explanation developed in this article provides a general alternative to the three current interpretations of hybrids. It is based on a longitudinal analysis of a landmark event at the academic-commercial boundary—the patenting by Harvard of an "oncomouse" genetically engineered for use in cancer studies, its exclusive license to DuPont, and the response from the scientific community to DuPont's attempts to impose commercial strategies on academia. The analysis shows that scientists were outraged by DuPont's use of the patent but at the same time started patenting themselves. This contradiction—which mirrors the contradictions in the literature on hybrids at institutional boundaries—can only be resolved by exploring the meaning that scientists gave to their hybrid exchanges and the processes that led to their production. The evidence suggests that scientists changed the traditional meaning of patents and incorporated them into hybrid exchanges at the boundary as a means of maintaining (and even strengthening) the distinction between the academic and commercial logics. Consequently, while patents changed the boundary between academia and commerce, scientists' boundary work changed patents. In doing so, it produced hybrids that maintained the two worlds in productive tension.

More generally, by understanding the meaning of hybrids and the processes of their production, we observe that hybrids can be produced through the pursuit of differentiation, rather than by blending, and are maintained in productive tension rather than through easy coexistence. As this article demonstrates, to observe hybrids—both in the specific case of the academic-commercial boundary and for many other complex boundaries—can be to see the traces of tension as skilled actors take the resources of one logic, transform their meaning, and thus establish differentiating hybrids. It can also be to observe the result of boundary work aimed at maintaining the distinction between two institutional logics, not a blending or dissolving boundary.

I elaborate on the mechanisms producing differentiating hybrids and their implications for our interpretation of overlapping institutional boundaries in the following sections. Section I provides the theoretical grounding of this approach to institutional logics and exchange strategies and describes the "pure" strategies traditionally characterizing the academic and commercial worlds. Section II outlines the oncomouse case as a window into the academic-commercial boundary in mouse genetics, the methodological approach to the case study, and a timeline of the pivotal events in this story. Section III describes exchange strategies used by

mouse geneticists before and after the oncomouse was patented. Section IV then examines the meaning and interpretation of the hybrid exchange strategies that emerged after the oncomouse was patented. Section V explains the implications of these findings for institutional theory.

I. OVERVIEW: LOGICS AND EXCHANGES IN ACADEMIC AND COMMERCIAL SCIENCE

With few exceptions (Biagioli 2000, 2006), previous studies of the academic-commercial boundary focus on the inscriptions of science and commerce: patents, publications, and contracts. But by dissociating resources from their meaning in social action, this approach cannot accurately describe the mechanisms at work at the boundary, or the meaning of exchanges to those producing them. In contrast, the analysis that follows builds a rich description of these resources as they are exchanged in everyday scientific life, how they are produced, and the meaning they convey. My approach is grounded in sociology of institutional change (Leblebici et al. 1991) and cultural and political analyses of the boundaries of science (Gieryn 1985, 1999; Frickel and Moore 2006). It recognizes that while logics operate at multiple levels of jurisdiction in society (Jepperson 1991; Scott 1995), they are most clearly enacted by individuals who provide meaning to their social reality through strategies of action (Swidler 1986; Friedland and Alford 1991). By attending to strategies of action as enacted through exchange relationships—exchange strategies—we capture the engine of social relations that drive institutional logics (Padgett and Ansell 1993; Bacharach et al. 1996; Stark 1996). Moreover, highlighting that individuals undertake artful manipulation of resources to serve their purposes and produce exchange strategies "not only in terms of material interests . . . but in terms of the symbolic meaningfulness of that participation," this approach allows for the idea that scientists produce hybrid exchanges from commercial resources but at the same time may transform the meaning of these resources (Friedland and Alford 1991, p. 250). Before analyzing such hybrids, it is useful to outline the "pure" exchange strategies that have held sway within the traditional logics of academic and commercial science.

What makes these spheres distinctive institutional logics, rather than simply different types of knowledge, lies in the practices, incentives, and strategies of action that they support and take for granted in the course of knowledge production (Nelson 1959; Rosenberg 1974; Dasgupta and David 1994; Mokyr 2002). Moreover, while the precise definition of pure versus applied knowledge has repeatedly shifted and can merge into dual-use knowledge (Stokes 1997), the logics of academic and commercial sci-

ence and the social groups that constitute these logics remained relatively stable (see table 1 for a summary).

The logic of academic science attends to the pursuit of knowledge for knowledge's sake. Like other university-based scholarly pursuits in the humanities and social sciences, it is subject to the exchange cycle of knowledge production, disclosure, and reward. Disclosure takes many forms: scientific materials, instruments, and tacit knowledge (Collins 1974, 1998). However, publication is the predominant means of disclosure and initiates an exchange that lies at the heart of the institutional logic of academic science: knowledge described in a publication is a gift made in exchange for the hope of recognition and adjudicated by peers through the review process (Hagström 1965). The fight for priority is the engine that energizes the disclosure of scientific results (Merton 1957). Recognition is directly valued by those who engage in academic science and is reinforced and translated into future resources through a cycle of credit (Latour and Woolgar 1979).

In sharp contrast, the institutional logic of commercial science is directed at turning ideas into private property and economic rewards, elaborating a logic built around the degree to which a scientist can exclude others from replicating his work and thus appropriate the value created by that knowledge (Nelson 1959; Arrow 1962; Levin et al. 1987). This protection was traditionally achieved through secrecy. However, recognizing that disclosure provides an important efficiency in the economy, governments developed incentives for disclosure; namely, patents granted in exchange for the provision of intellectual property rights that give a (time-imited) legal right to exclude others from practicing the same invention. Typically, patents are filed by an organization (e.g., corporation) on behalf of an inventor. From the outset, the production of patents, therefore, is in the hands of a variety of actors not found in the traditional scientific logic. While publishing is a matter for individual discretion (in academia), patenting (in industry and academia) is undertaken at the discretion of different constituencies: university administrators or industrial managers, technology transfer officers (TTOs), lawyers, and investors. Legal guidelines define the "rules" of patenting. These laws cover not only what constitutes patentable matter but also the requirements that the ideas be nonobvious, novel, and useful. These standards are more broadly applicable (but bounded) compared to standards in publishing, which vary by journal. The adjudication of patentability does not operate through a peer-review system. Instead, a patent office and its professional examiners make this determination through a series of negotiations that include the scientist and lawyers (Cockburn, Kortum, and Stern 2003). As a result, while disclosure through publication takes only a few months (in the physical and life sciences), the granting of a patent takes an average

TABLE 1

Differences between the Logic of Academic Science and Commercial Science

	Logic of Academic Science	Logic of Commercial Science
Broad elements of institutional logic:		
Producer of knowledge	Author—defined by convention and negotiation	Inventor—strict legal definition
Formal disclosure inscription	Publication	Patent
Adjudication of disclosed claim	Peers	Patent office/court
Rights with "accepted" disclosure	Time-unlimited priority rights	Time-limited intellectual property rights
Rewards	Priority leading to credit, recognition, and status	Rights leading to exclusion and the right to appropriate licenses
Exchange requirements of institutional logic:		
Requirement to trade/exchange	Strong normative requirement (w/different terms)	No obligation to trade
Market for exchange	Some flexibility—collaboration, citation (gift), acknowledgment	Highly differentiated and flexible—complex variety of contractual elements
Exchange partners	Homogeneous—other scientists	Heterogeneous—many types of firms and other actors
Other exchange requirements	Yes—presentations, materials, tacit knowledge	Yes—materials, tacit knowledge, expertise, etc.
Sanctions	Normative, self-governing	Legal, external actors
Link to prior ideas	Citations—gifts—also establish and strengthen claims	Citations—legal requirement can weaken value of claims

of three years. The negotiation of rights continues after a patent is granted, with "interested" parties having the right to challenge the patent in formal legal proceedings (not through peer scientists, who adjudicate claims of fraud in academic science).

Like publications, patents also establish priority for their inventors; however, this is incidental to the property rights that are conferred to their owner and serve to complete the commercial logic of exchange, since they can be used to extract economic rewards from others. In addition, an important feature of a patent is that it distinguishes between the inventors—those individuals who developed the ideas—and the owner (assignee) of the property rights, with the result being that the rewards of patenting can be contractually transferred to others and can be captured by the owner, with or without the agreement of the inventor.

While the institutional logics of academic and commercial science are conceptually distinct, they do not operate in isolation. Indeed, throughout the 20th century, the boundary between academic and commercial science was characterized by the movement of students trained in academic laboratories into the private sector to pursue projects of industrial interest (Galambos 1979; Hounshell and Smith 1988; Reich 1992). And, justifications for the pursuit of science according to the academic logic rely on the assumption that science will bring "higher standards of living" (Bush 1945). Thus, a porous boundary has been and continues to be a necessity and a historical reality. However, in the late 1970s, amid a slowing U.S. economy, critiques sought ways to more tightly couple the academic-commercial boundary. In response, the 1980 Bayh-Dole Act gave universities the right to own intellectual property developed from federally funded research (Mowery et al. 2001). The law's aftermath saw a massive rise in academic patenting and a highly contentious period on campuses across America (Colyvas and Powell 2006; Colyvas 2007).[2] Armed with their patents, hybrid exchange strategies emerged that included patents, publications, and other commercial tropes. However, the implications of these hybrids for the academic-commercial boundary are unclear.

II. THE ONCOMOUSE AS A CASE STUDY

The exchange strategies of life scientists in this changing institutional context offer a natural context in which to probe the properties of hy-

[2] Between 1989 and 1999, U.S. research universities received over 6,000 life science patents (Owen-Smith and Powell 2003). Recent studies reveal that among 5,000 U.S. life science academics, over 25% have received patents (Stuart and Ding 2006). In a sample of publications by a similar group, over 50% were associated with patents (Murray and Stern 2007).

brids—their meaning, development, and institutional implications. The special place of the life sciences community arises from two developments. First, academics in this area were quick to recognize that their discoveries were also the foundation of commercial products that, following the Bayh-Dole Act, could easily be published and patented (Murray 2002). Second, a critical 1980 Supreme Court decision expanded the scope of patent law, confirming that discoveries such as simple modified organisms and later mammals (including the oncomouse) could be patented. In this context, the oncomouse discovery in 1984 provides a prominent early example of scientific knowledge that was both published and patented. Consequently, the history of the community of mouse geneticists touched by its discovery is of signal importance in understanding the widely observed but differently interpreted hybrid exchanges (particularly the role of patents). Its importance also stems from several features that allow for clear identification of the impact of imposing patents on academic science:

1. The patent was issued early on in the wave of academic patenting.[3] It was therefore a shock to most mouse geneticists, none of whom had patents at the time.
2. After the patent rights were licensed exclusively to DuPont, the firm demanded extensive commercial terms from the academic mouse genetics community.
3. The oncomouse was quickly recognized as an important idea, making it unattractive for researchers to simply switch to a different research line in the aftermath of the patent.
4. The publicity over the patenting of the oncomouse rippled through the entire life science community, guiding subsequent practice among many other researchers.

Key institutional features of the timing of patenting and publishing a discovery like the oncomouse also make it a particularly attractive case from an analytic perspective: if a scientist (in academia or industry) generates scientific knowledge that can form the basis of a discovery and an invention, then he or she can make the strategic decision to disclose that knowledge in a scientific paper and seek patent rights. If this scientist is successful in both institutional logics, it will lead to a phenomenon referred to as a patent-paper pair—a paper and its "paired" patent that disclose the same piece of knowledge (Ducor 2000; Murray 2002). Specific insti-

[3] Between 1982 and 1984, academic patenting in biotechnology was still relatively unusual: the top 10 universities for biotech patent applications (ultimately granted; defined by U.S. codes 800/001, 435/172.3, 435/240.1, 435/240.2, 435/240, 435/317.1, 935/032, 935/059, 935/070, 935/076, and 935/111) were the University of California, Columbia University, MIT, the University of Texas, Harvard, Stanford, Caltech, the University of Wisconsin, Cornell, and Johns Hopkins University.

tutionalized practices around the timing of peer review versus patent review establish a time window of about four years between publication and the grant of patent rights and provide a natural experiment; we can examine exchange strategies in two periods that differ only in whether they arise before and after the granting of the patent (an approach that has been used in quantitative work but not in any qualitative analysis; see Murray and Stern 2007).

The oncomouse case also illustrates how the social lives of actors can be revealed in depth by examining "the cognitive aspects of major collective events in which large numbers of persons rapidly adopt orientations that might have appeared culturally alien to the majority of them a short time before" (DiMaggio 1997, p. 280). This strategy is not new in the sociology of science. After all, routine assumptions and consensus over practice are hard to identify (Scott, Richards, and Martin 1990; Rader 2004). It is often only in moments of transformation, when these assumptions are challenged, that scientists reveal their thinking about taken-for-granted aspects of their milieu. The oncomouse event is one such moment.

Case Methodology

This study combines three types of evidence (see Zelizer [1989] for a similar methodological approach): (*a*) interviews with members of the mouse genetics community who were engaged in scientific research during the period of the oncomouse controversy; (*b*) contemporaneous documents generated by the mouse genetics community during the oncomouse controversy; and (*c*) bibliometric research on citations to the oncomouse publication, review articles on the oncomouse techniques, and patent citations to the oncomouse patent. I conducted all interviews either in person or by telephone and prefaced each discussion with a brief introduction to the purpose of the research. I collected over 60 hours of interviews with 11 junior (assistant professors or postdoctoral students at the time of the case) and 18 senior scientists (tenured faculty at the time of the case, of whom 6 were regarded as leading figures in the field at the time of the oncomouse), 6 TTO professionals, 4 lawyers, 3 corporate executives, and 2 administrators. These subjects worked at various universities and related organizations.[4] The scientists who were interviewed represented a sample of the mouse community engaged in this field, as identified from publications of transgenic mice and citations to those publications in the four years preceding and following the oncomouse publication. Most of

[4] To assure the anonymity of participants, I refer to the persons I interviewed by their professional characteristics instead of by name.

their names had appeared repeatedly in popular discussions of the oncomouse patenting decisions, and each individual had made at least four contributions to the oncomouse literature and appeared on the roster of mouse genetics meetings at Cold Spring Harbor Laboratory. My interview subjects can therefore be characterized as central researchers in this field rather than peripheral ones. At least half of them have an extremely high status within the field of mouse genetics, with numerous publications and awards. The remaining interviewees are drawn disproportionately from high-status universities. However, these are the universities where most of the mouse genetics research was taking place at the time the oncomouse was discovered. Therefore, while the analysis is built on their perspectives, we can expect that these perspectives are representative of the core researchers in the field. The reliability of my interview evidence is strengthened by the agreement that emerged among multiple sources, or with key events being recounted and corroborated by different individuals. The lawyers, TTO professionals, and administrators all had firsthand experience of the case, either as participants in the initial patenting and licensing or as the agents of universities that hoped to be recipients of mice. The majority of the interviews were with those on the academic side of the story, and this is the perspective taken throughout the analysis. The question of how and why DuPont constructed its licensing strategies is not the subject of this particular article. However, my data include four interviews with executives from the pharmaceutical industry and animal suppliers.

The interviews were retrospective in nature and focused on the timeline of the oncomouse discovery, patent, and subsequent controversy, rather than on current practice. In all instances (where relevant), I explored how exchanges were struck in the period just after the oncomouse discovery and how exchange strategies were developed to accommodate the new material characteristics of the oncomouse prior to the patent. Scientists' attitudes toward the oncomouse patent were then examined. What understanding did academic scientists have of patenting? What was their response to the oncomouse patent? Did they use the exclusionary tactics that are a central feature of patenting? How have scientists incorporated patents into their strategic calculus of finding collaborators, acknowledging the work of other scientists, and exchanging research material? I also made extensive use of documentary evidence to provide more contemporaneous (albeit public) discussions and quotes regarding these events.[5]

[5] Primary documentary sources include (1) the editorials, opinion pieces, and letters from the leading scientific journals *Science* and *Nature*; (2) archives of speeches, interviews, and award salutations from major scientific-prize-awarding organizations, including Nobel and Lasker; (3) historical accounts of the mouse genetics community

Bibliometric analysis was especially useful in revealing changes that took place as a result of patenting the oncomouse. Studying and comparing patent applications and scientific publications of that era were crucial for understanding the impact of patenting on hybrid exchanges. Analysis based on the academic literature helped in reconstructing the network of coauthoring collaborations defined around the oncomouse as well as informal relationships documented through acknowledgments in publications. For the period prior to the oncomouse patent grant, publications citing the oncomouse paper and those described in contemporaneous reviews published between 1984 and 1989 (60 peer-reviewed articles) were analyzed for coauthorship patterns and acknowledgments.[6] The interviews, documentation, and bibliometrics were used to construct a historical narrative of events surrounding the patenting of the oncomouse. The subsequent analysis was developed iteratively, by systematically exposing the features of exchange in each period and the mechanisms at work producing these exchanges. Interview material was repeatedly compared with documentary evidence and bibliometrics, including follow-up interviews with 10 interviewees (4 repeat and 6 individuals identified as salient to the events) to confirm understandings, explore differences in meaning, and elaborate the meaning of described practices.

Timeline of the Oncomouse Case

The development of the oncomouse grew out of a revolution in the late 1970s when mouse genetics was rocked by the power of molecular biology (Morse 1981; see fig. 1). A leading member of the mouse community described the events that ended the field's "classical period": "Then, at the end of 1980, in a period of a few months, an entirely new era in mouse genetics began, with the creation of the first transgenic mice, initiated by the abrupt and then continuing entry of molecular biological techniques into what had, until then, been a classical genetic system. What ensued was an explosion of knowledge when a myriad of new biological and molecular insights appeared over the following years. Although certainly built on the past, the new science quickly developed a life of its own and thus deserves its own chapter" (Paigen 2003, p. 7).

This disruption was initiated by a classic example of "multiples" (Merton 1957): five independent teams published the development of transgenic mice. They described that when foreign DNA (a so-called transgene) was

found in the Jackson Laboratory Archives; (4) newspapers, including articles and editorials (mainly the *New York Times*).

[6] This captures research up to 1990, when the OncoMouse patent rights are enforced, and includes reviews by Cory and Adams (1988), Palmiter and Brinster (1986), and Hanahan (1988, 1989).

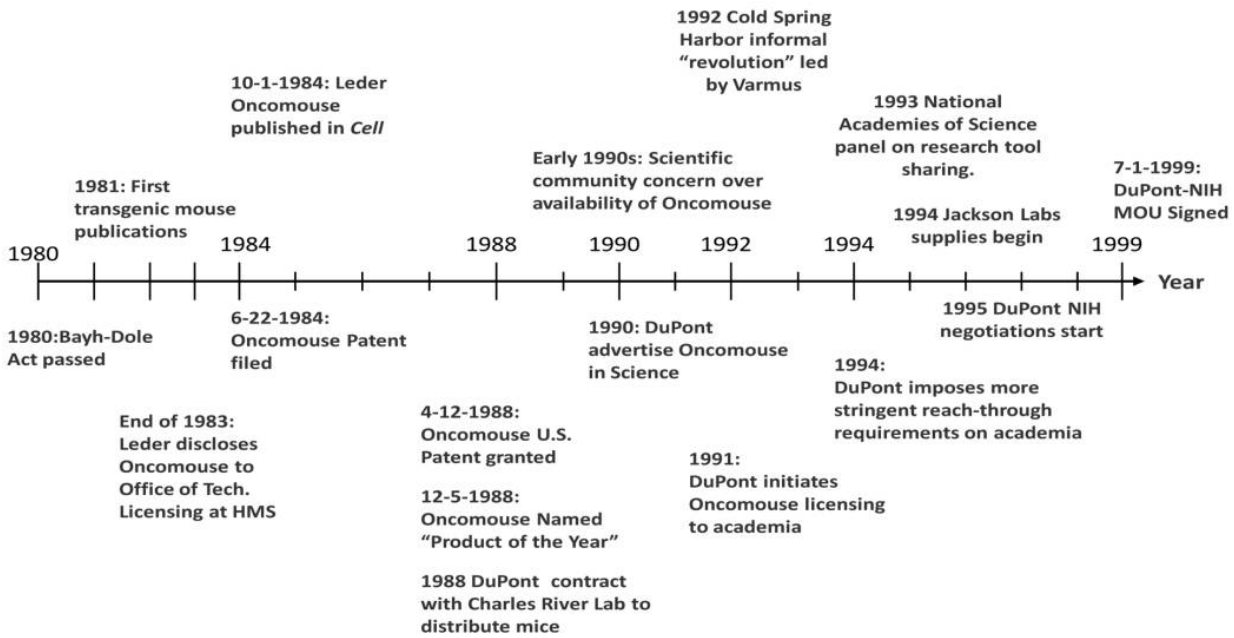

FIG. 1.—Timeline of major events in the OncoMouse case

injected into mouse eggs, which were then transplanted into female mice, the genes were incorporated into the offspring, creating a "transgenic" mouse. These transgenic methods solved an important methodological gap in whole mammal biology—they allowed the insertion of a known gene into a mammal, allowing researchers to monitor its function in the whole organism. Among the first to recognize the potential of these mice were scientists studying cancer. During the classical period of mouse genetics, cancer researchers relied upon chemical and radiation-based methods to induce cancerous mutations in mice, but the entire program suffered from a lack of precision (Morse 1978). During the 1970s, cancer biologists had responded to these limitations by shifting their focus to the cellular level, where they identified an intriguing class of cancer-related genes—so-called oncogenes. However, while oncogenes had been analyzed in cell lines, "their action in a living organism is, at best, incomplete" (Stewart et al. 1984, p. 627). It occurred to mouse geneticists that oncogenes could be introduced into mice via transgenic methods to produce a valuable "oncomouse"—a mouse engineered for the study of cancer.

In 1984, two teams succeeded: the Palmiter and Brinster labs, in collaboration (among the first to develop transgenic mice), and a laboratory led by Phillip Leder, chair of the department of genetics at Harvard. In the 1970s, Leder, like many cancer researchers, had focused on genetics at the cellular level, using mouse cells rather than mice themselves. He also had more than a passing interest in oncogenes, spending several years studying a particular oncogene (*Myc*) implicated in a rare form of lymphoma. While his lab had not pioneered transgenic methods, Leder had recently hired Timothy Stewart, a postdoctoral scientist well versed in the methods as a member of one of the five successful teams in the early transgenic mouse developments (Wagner et al. 1981). With Stewart's expertise, Leder's group created a viable mouse that carried the *Myc* oncogene and therefore had a predisposition for cancer. The competing teams published their experiments in the prestigious journal *Cell* within a few months of one another: Palmiter and Brinster in June 1984 (Brinster et al. 1984) and Leder in October 1984 (Stewart et al. 1984). The *Cell* article was not the only way in which Leder wrote up his oncomouse discovery. On June 22, 1984, two months before submitting to *Cell*, Harvard filed a patent application on the oncomouse. This decision can be traced to 1983, when Leder approached the Harvard Office of Technology Licensing to discuss the patentability of his research (Kevles 2002). DuPont was also involved in these discussions, as Leder described: "The work that we did was supported, actually, by an industrial concern, DuPont. They made a significant investment in that research and this is one of the products that could emerge from it, and did emerge from it, and they are incentivized to make further investments in this process by virtue of the

return that they will receive [from the patent]. That is our system. You may like it—you may not like it" (Lasker Foundation 1987).

Between 1981 and 1984, DuPont had awarded Leder over US$6 million in grants that, together with National Institutes of Health (NIH) awards, supported his research. DuPont's funding was made under an agreement that ensured no restrictions be placed on Leder's freedom to publish or discuss his research. Nonetheless, DuPont required that Leder have any new discoveries assessed for their patentability. The other team (funded by NIH, the National Science Foundation, and a graduate fellowship from SmithKline Beecham) did not file patents, although under the terms of Bayh-Dole, it was free to do so. The patent application remained confidential until, on April 12, 1988, the U.S Patent Office (USPTO) granted patent 4,736,866, whose first claim was: "A transgenic non-human mammal all of whose germ cells and somatic cells contain a recombinant activated oncogenes sequence introduced into said mammal, or an ancestor of said mammal, at an embryonic stage" and therefore provided property rights over the oncomouse and other transgenic mice and mammals.

The arrival of the OncoMouse (trademarked in 1990: USPTO serial number 74026911) in the commercial world was loudly signaled when *Fortune* named it "Product of the Year." For the public, the patent proved controversial, being the first to be granted on a mammal. However, the controversy in the scientific community was not the legality of the patent, but Harvard's exclusive license to DuPont, which gave the firm the right to "make and have made, to use and have used, to sell and have sold, *the licensed product* [in this case, the oncomice], and to fully exploit the patent rights" (Peterson 1993, p. 458).

III. EXCHANGING THE ONCOMOUSE

The DuPont-licensed patent eventually led to the transformation of the institutional boundary into one formed by hybrid exchanges in which actors (in academia and industry) imbued the same tools (patents) with distinctive meanings in order to conduct exchanges that maintained the differentiation of their worlds and achieve their often divergent goals. Before analyzing this hybrid boundary (in Sec. IV), Section III outlines the evolution of the hybrid strategies, their meaning, and the controversy they produced by exploring the oncomouse in four historical eras or acts: (1) the initial exchanges in the four years prior to patent grant, (2) the controversy of the oncomouse patent, (3) the variety of exchange strategies that followed, and (4) the final compromise reached between DuPont and

the mouse genetics community. I end Section III by looking behind the scenes at the strategies that also emerged but are less widely discussed.

Act 1 (1984–88): Academic Exchange Strategies for the OncoMouse

While Leder's team and the Palmiter-Brinster collaboration led to the development of oncomice, the challenges of making and using these mice remained significant. The techniques required practice and skill (Collins 1974) and had not, as yet, been reduced to simple "kits" (Fujimura 1996). To create an oncomouse, one needed to have "magic hands": even under the best conditions, the uptake of cloned genes into the embryos was only 10%–25% efficient (Cory and Adams 1988). In addition, development of breeding lines that reliably transmitted the transgene required an array of traditional skills. This is how one of the leading researchers I interviewed described the challenges of training someone: "With [X] we didn't have to spend much time perfecting the technique. But that was because he was very good. You need someone with good hands and a good observer—that was [X] for you. Off the bat he started getting successful cases. I've tried to teach a succession of people, and it's not a teachable skill—some catch on right away and some never do a good job. [X] was just a natural" (leading researcher, embryologist).

Struggling with how to share oncomice and what the terms of exchange might be, scientists in the mouse community explicitly referred to their long tradition of openly sharing research mice, asking for little more than acknowledgment in future publications. In this spirit, the Jackson Laboratories (JAX) in Maine had been established to support the maintenance and development of mouse strains for free exchange; it began the sale of strains in 1993. Other organizations and informal associations further increased the availability of experimental mice and the data produced by their use. Together with the ease of access afforded by JAX, exchange norms emerged that encouraged researchers to use mice as a communal resource. These norms went beyond the strains shared by JAX. Researchers widely traded specialized mouse stocks not available from suppliers (Silver 1995). Philip Leder reflected on the ethos of biological research in the 1960s and early 1970s: "I think that scientists at that time were very willing to share the information they had gained. Of course [they] desired some attribution or credit for that work because what you work for in this business, perhaps the most valuable reward, is the grudging appreciation of a few colleagues who really understand what you are doing. Once you are satisfied that you have got that, which probably no one ever is, then you are quite willing to share . . . anxious to share . . . enthusiastic about sharing the results of your work. That is really what

you live for" (Leder, leading geneticist and discoverer of the oncomouse, quoted in Lasker Foundation 1987).

These norms had substantive scientific implications: mice became as important as the fruit fly or worm and developed into "standard research organisms . . . and iconic symbols of the value of standardization within our culture" (Rader 2004, p. 7). Its genetic likeness to humans (99% homology) made it particularly central in the study of cancer (Boguski 2002). The shared resources and relationships also allowed researchers to identify doable problems, gain faster results, and build a consensus on their meaning (Kohler 1994; Fujimura 1996; Rader 2004).

In 1984, against its generous traditional material culture and strong normative pressure for exchange, mouse geneticists struggled to find appropriate exchange strategies for oncomice. Analysis suggests that while they aspired to the normative exchange principles, most believed that more complex exchange strategies were required. They argued that the material nature of transgenic mice restricted the community's ability to exchange widely and "cheaply." The mice were fragile, and breeding lines had not been stabilized. This made it difficult to share in large numbers. One scientist who had managed to make oncomice in the late 1980s recalled: "I had a few requests for mice and offers of co-authorship. But I did not send them the mice. I sent a long and detailed explanation of the implausibility of the request. The mouse line died very young. Over the period I was having to slow my own work down because they were breeding very poorly and so it was impossible to ship them around" (author interview, senior full professor in developmental biology). Moreover, the mice were hard to engineer. One leading scientist from that period commented: "At the start I was accused of not being forthright in outlining my methods. [Aside: I knew they were saying this because mutual friends told me.] But of course people spoke too soon. Of course you can't do this sort of work if you're clumsy. In the fullness of time my detractors came to realize that I was right. It was just a question of having the prior background" (author interview, senior full professor in mouse genetics and embryology).

Given the academic value associated with the mice, successful labs were not willing to widely exchange their oncomice (even if they could) or their skills in return for recognition only. Researchers recognized the oncomouse as a breakthrough for the study of cancer: "The creation of transgenic mice carrying specific cancer-promoting genes opened an exciting new era in oncology" (Cory and Adams 1988, p. 25). As such, they wanted to provide the field's leaders and their students with opportunities to benefit from their pursuit of the complex task of transgenic mouse development, while still moving the field forward.

Publications using oncomice in this period provide some insight into

the exchange strategies that emerged. Scientists who published novel results using oncomice had only been able to do so using a series of intricate exchanges to access the requisite materials and methods, forming an "invisible college" around the originating labs (Crane 1969). They traded skills in building an oncomouse rather than the mice themselves. Methodological expertise was an important source of prestige and advantage (Hackett 2005) exchanged through lab-to-lab collaboration (and coauthorship). Embryonic manipulation, maintaining strains of mice, and breeding new ones were skills not typically available to cancer biologists (who worked purely at a molecular level or who relied upon JAX). In return, they brought knowledge of molecular biology. One such collaboration (later to become infamous in a case of scientific misconduct [Kevles 1998]) was struck between David Baltimore and Frank Constantini (an early transgenic pioneer). As part of the exchange, Baltimore sent Constantini the gene; in turn, he created mice that were sent to Baltimore's lab, while faculty coauthored publications (e.g., Weaver et al. 1987).

At times, exchanges between laboratories failed. One scientist described how he sent a colleague material with explicit instructions as to how it should be used. The colleague "totally violated all the stipulations I had made then published an outrageous paper. It does have my name on it but that's because when I saw the first draft I told him he should do the experiments differently, and I felt that made me an active participant. . . . But this is not collegial behavior" (author interview, senior full professor in mouse genetics).

Exchange could also be established through the movement of people (Slaughter et al. 2002). Leder himself had engineered the oncomouse by combining his own expertise in oncogenes with the expertise of Stewart, who had come to Leder's lab as a highly trained postdoc. Steward's rare talents brought him first authorship on important publications with Leder and later a sought-after position at Genentech. Other labs also brought in students trained at the benches of pioneering transgenic experts. The director of one lab with expertise described getting "an uptick in applications from people wanting to do postdocs and learn the methods so they could take them elsewhere and gain fame and fortune" (author interview, full professor in developmental biology). A few postdoctoral students had enough experience to set up independent labs (taking mice with them) and build their own stream of research, exchanges, and reputations around oncomice.

Overall, however, exchange strategies were difficult to negotiate. As one expert noted: "Nothing activates the baser form of human nature than the possibility that they can claim more fame if they say they did it all themselves. And this was truer in these mice than in most other areas I've worked in" (author interview, full professor in genetics). Not everyone

was sanguine about exchanging their mice. An informal poll in *Science* described the exchange experiences of scientists over a cousin of the oncomouse (a knockout mouse) developed by Nobel Prize winner Susumu Tonegawa. They found that of 15 researchers Tonegawa claimed to have given mice to, 3 received them a year later from a postdoc in his newly founded lab, 1 was turned down as a competitor, 4 received mice with the stipulation of direct collaboration, and 6 said they had never approached Tonegawa because of his reputation, instead going straight to his postdoc (Cohen 1995). While there were no official sanctions, public denouncement for lack of a collegial exchange strategy was damning.

In the late 1980s, the appropriate norms of exchange remained in flux in academia, with some calling for internationally acceptable and consistent guidelines to remedy the difficulty scientists were having in establishing their own exchange practices. Scientists recognized that one of the prerequisites for more extensive mouse exchange was breeding efficiency—it was costly to establish a communal resource unless breeding was straightforward. "We [the community] needed an ambitious and well-supervised [breeding] operation" (author interview, junior professor of mouse genetics). In early 1989, discussions opened with JAX regarding the breeding, exchange, and standardization of oncomice. At precisely this moment, DuPont appeared with the oncomouse patent, and scientific life changed dramatically for the entire mouse genetics community.

Act 2 (1988–91): Initial Academic Outrage at the Harvard Patent and DuPont License

In 1988, DuPont received an exclusive license from Harvard to the oncomouse patent, and, by 1991, executives had trademarked the mouse and implemented new terms of exchange, based on principles practiced in commercial science. As they attempted to strike a richer exchange with scientists wanting to use the mouse, it became clear that standing on the shoulders of the OncoMouse would come at a considerable cost (Blaug et al. 2004). In the market that DuPont envisioned, the prevailing currency would be financial, relationships would be contractual (not informal), and exchanges would involve more parties: academics, TTO officials, lawyers, and corporate executives. The actual cost of the mice was about $50, roughly 10 times the price of a JAX mouse (Anderson 1988), but the dollar terms were not what troubled academic scientists. In addition, DuPont sought three more commercial terms of exchange. First, they placed limits on the informal exchange of mice: DuPont would not allow scientists to follow their traditional practices of sharing mice or breeding extensively from the mice. This was true for scientists who had bought a "sanctioned" OncoMouse from DuPont but was also true for scientists who generated

an OncoMouse in their own laboratories. Second, DuPont imposed contractual controls over scientific disclosure, most notably, a requirement that scientists fulfill annual disclosure requirements—not a prohibition on publishing or a publication oversight, but rather, a requirement that scientists using an OncoMouse would report annually on their published (and unpublished) findings. Third, DuPont imposed reach-through rights on future discoveries made with an OncoMouse, requiring that scientists give them the rights to any future inventions made using an OncoMouse. These rights gave DuPont a percentage share in any sales or proceeds from a product or process developed using an OncoMouse, even though the mice would not be incorporated into the end product. None of these terms were integral to patent law but instead were different elements of the new exchange strategy DuPont crafted. While common in exchanges between biotechnology and pharmaceutical firms, this was the first time a company had sought to reach across the academic-commercial boundary and impose such commercial exchanges on academic scientists. The nightmare of "hostile worlds" protagonists—that the powerful arm of the market would reach into academia and engineer its collapse—seemed about to unfold.

Although DuPont announced the arrival of the OncoMouse in a full-page advertisement in *Science*, heralding a "potentially disruptive and radical" new research tool, scientists discovered the specifics of their proposed exchange strategy slowly. Some heard from colleagues, others in a phone call from their TTO. When scientists approached DuPont's OncoMouse supplier—Charles River Labs—they found bewilderingly complex exchange conditions that struck at the core of emerging academic exchange strategies. Scientists objected to each of DuPont's terms, especially the breeding and exchange restrictions. As described in Act 1 above, even for those embroiled in the complex OncoMouse exchanges, the traditional exchange strategies provided an important rhetorical and philosophical touch point. Historically, mouse sharing had made a substantive contribution to cancer research. Scientists raised practical, historical, and philosophical objections to DuPont's restriction on sharing mice.

As the rules were interpreted in the early 1990s, if a scientist whose transgenic mouse infringed on the Leder patent wanted to share strains with colleagues, he faced three annoying requirements: he had to complete a DuPont material transfer agreement (MTA) every time a colleague requested a mouse, he could only send the mouse if both his own and the other institution had signed a license with DuPont, and he was required to report on how it was to be used, keeping DuPont informed of the progress of each project. The requirement to submit annual reports was also highly inflammatory to many in academic science. Issues of secrecy,

the "gagging" rights of companies in cases of corporate-sponsored research and publication delay, had already been controversial at Harvard in the 1974 debate over Monsanto's research sponsorship (Cooke 2001). However, DuPont's conditions went beyond this. They were claiming rights without providing funding. For scientists in the mouse community, the notion of commercial reach-through rights was disturbing.

On the surface, the negative reaction by scientists in the mouse community to reach-through rights may seem perplexing. Since many of these scientists had never been interested in the commercial fruits of their research, why should they care if someone else wanted to exploit the commercial potential of their work? Furthermore, scientists had long negotiated something akin to these control rights when considering the complex expectations of authorship versus citation as the currency for a resource exchange (Biagioli and Galison 2003). However, these claims were quite nuanced and weakened over time as ideas and methods became more widespread. In contrast, the imposition of rights to an ongoing "research" stream based on intellectual property was antithetical to both local and universal scientific practice. As two scientists put it:

> In science we always try and appreciate a new idea and give credit. People with something new hold onto it for a while and we collaborate with them but over time these rights weaken and ideas become mainstream. No one monopolizes them forever. If they do, they just won't reach the sort of widespread acceptance that is so vital to our field. (Author interview, junior professor in cancer biology)

> Sometimes firms that sponsor our work come in and try and negotiate the right to an authorship on every paper that we write. I always have to explain that authorship is not for sale. . . . You have to make a real contribution. There is no automatic credit in our field. (Author interview, junior professor in molecular biology)

DuPont countered by claiming that the licensing terms were not burdensome: the license was "free," and the firm could "turn around a license to an academic user in two days to a week" (associate director, DuPont Intellectual Asset Business, quoted in Marshall [2002, p. 336]). However, it was not the transaction costs of patents (Heller and Eisenberg 1998) that were at stake, but rather, the loss of freedom for scientists to create their own exchange strategies and develop the material culture of their community. Their traditional autonomy had been shattered by DuPont. Their response was rapid and different from what scholars of the response to institutional pressures might have predicted (Oliver 1991). It unfolded along two paths until a formal compromise was brokered by the NIH: acquiescence to the new commercial exchange terms and resistance, in-

cluding both individual and community acts of disobedience (Ewick and Silbey 2003).

Act 3: Acquiescence and Resistance

Reluctant Acquiescence to Commercial Exchange Strategies

Akin to the predictions of "hostile world" theorists, in response to DuPont, some mouse geneticists slowly came to foresee a nightmare scenario. Many felt that they could not simply drop oncomice from their research agenda. "By the time the patent was granted, the method had become well established, and so even if you weren't using it before, you still would choose to continue and start to use the mice—it was so obviously a good idea" (author interview, leading mouse geneticist). As the success of the research line over the prior four years had shown, the OncoMouse was a valuable tool, providing a growing stream of new insights into the role of cancer in whole mammals. The advice they received from their TTO officers suggested that if they did not acquiesce to these conditions, they could not carry out their experiments. Because the mouse was so important for research, over 100 universities signed the license agreement. Nonelite universities may not have had the will or resources to oppose DuPont, did not have the research clout to make a strong stand, or had their hands tied due to state government politics (if they were state schools) or strong control by administrators over the actions of their scientists.

Resistant Academic Exchange Strategies

While perspectives on institutional boundaries typically take an "either/or" perspective when analyzing responses to institutional pressures such as an invasion of new exchanges (see, esp., Oliver 1991), the OncoMouse case suggests a much richer range of responses. While some acquiesced, a handful of important institutions, including the University of California, Harvard, Johns Hopkins, and MIT, refused to sign. This divergence in response created a significant tension in the previously tight-knit community. In the words of two leading mouse scientists:

> When DuPont was making noise about IP [intellectual property] and there were schools with licenses and some without, those who'd signed couldn't send a mouse to you if you were at a school who hadn't signed. It did start to create tension and a schism in the community. (Author interview, junior embryologist)

> It was an enormous obstacle to free and open distribution of information and materials. . . . It was a whole new way of doing science . . . it really affected the way the mouse research community works. (Klavs Rajewsky,

> senior faculty in molecular biology, University of Cologne, quoted in Jaffe [2004, p. 46])

Scientists expressed their concerns through a variety of strategies of resistance. More than simply grumbling to their interviewer, scientists detailed their use of civil disobedience—ignoring the rules, active contestation, and, at the most extreme, assaults on the legitimate authority of DuPont over their research. Oliver has argued that resistance to institutional pressures includes dismissing or ignoring explicit norms, assaults on the source of the pressure, and active contestation of rules (Oliver 1991). The mouse geneticists used all three strategies as mechanisms of civil disobedience (Ewick and Silbey 2003) in their exchange strategies and beyond. They also used private and public settings for resistance and to air the grievances of the entire community.

In private, some scientists chose to operate in the shadow of the law (Mnookin and Kornhauser 1979) "and simply breed their own oncomice, effectively boycotting the company" (Anderson 1993). This form of widespread infringement is consistent with recent survey results asking scientists whether they consider patents when designing experiments (Walsh et al. 2003). However, it is more mindful insurrection than benign neglect of the details of patent law: "I knew there was a patent on the use of isogenic DNA but I did not think about getting a license. I suppose that every once in a while we heard from DuPont or our TTO but it was rare that a patent holder challenges an academic institution, so in practice I didn't think twice about just going ahead" (author interview, junior faculty in mouse genetics).

While ignoring the OncoMouse patent, scientists still incurred a number of costs: exchange strategies using "homegrown mice" required considerable research effort and time and were restricted to a smaller number of people with expertise. Nonetheless, scientists could still engage in their research and then publish and receive credit for their work through citations if they wished, although not at the rate they might expect, given the challenges of crafting follow-on strategies for exchanging mice. By each using their own mice, scientists undermined their own tradition of standardization so critical to the establishment of early mouse genetics (Rader 2004). They were unable to compare research results and start developing these tools into a replicable and verifiable research system. One researcher active during this period stated: "I won't reject a mouse because of complex conditions, but it slows the process down, and if there is a choice, well sometimes it's easier to do it yourself if you possibly can, and this is exactly what happened with DuPont. We just kept doing things ourselves, and that made it much more difficult to compare our work. I think it really slowed down the adoption of mice by industry too, because

just at the time we should have been generating all the basic information to make this a standard model we were slowed down" (author interview, leading faculty member, mouse genetics).

Local infringement took place behind "closed doors" (Meyer et al. 1983, p. 58), but the challenges of the patent situation led mouse geneticists to increasingly engage with a much wider variety of individuals than was typical: from legal counsel and TTO officers to corporate executives and commercial animal providers. Not surprisingly, a letter from DuPont saying that a faculty member was in violation of a patent and exhorting the university to sign a licensing agreement came as a surprise and could ignite acrimonious debate (Marshall 2002). Some faculty happily voiced their opposition to the university and justified their resistance, but others lived under a cloud of fear (Smaglik 2000). One scientist noted, "Certainly we did butt heads with the TTO, both with respect to incoming and outgoing stuff and the details of the stuff we'll send." University administrators had different reactions to the notion of patenting and licensing streams on mice. He continued, "I will sometimes scream and shout but I'll give up [arguing] with the TTO many times because I am worn down and it takes months. . . . I delegate to postdocs or a lab manager but they are inexperienced" (author interview, senior scientist in mouse genetics). The TTOs also faced a complex and ambiguous challenge as they sought to recognize the needs of their scientists, their own interests in licensing, and their role as an interface with the commercial world:

> Most of our scientists did not want us to sign, and in fact we [in the TTO] had a lot of reservations too. We could not use the mouse for sponsored research . . . because that was commercial and continued to be an issue for us with DuPont and a point of contention, particularly if the sponsor of our research did not have a license already. We were trying to negotiate with DuPont, but they were not very keen on negotiating with us. We also worried about the obligations that came with signing a license. One of the issues is that by signing you have to undertake due diligence, you need to be vigilant about who the mice are sent to—you are now responsible. (Author interview, TTO)

Debate also moved outside the walls of the university. The annual CHSL Mouse Molecular Genetics summer conference became a public forum for scientists' critiques and a central organizing point for community-based attacks on the legitimacy of DuPont's actions. Scientists' concerns over restrictions on the use of oncomice were heightened because GenPharm International, a California biotech firm, had emulated DuPont and placed similar restrictions on a new "knockout" mouse—a cousin of transgenic mice in which key genes are removed (knocked out) rather than inserted (as in the case of the OncoMouse). DuPont also restricted

access to another key technology used to make another type of knockout, known as "*Cre-lox*." Some initially tried to excuse the firms as outsiders to the mouse community with no prior experience in the community's norms or practices. While that sufficed in the early days, scientists got tired of the firms' repeated insistence that their practices were appropriate. Others countered that this made poor business sense: "I mean, I think it was a stupid business practice. Why didn't they simply recognize that people weren't buying and so they should lower the cost, whatever those costs might be? I mean I know the cost to industry to keep firms from adopting the mice because they would tell me, and this is unfortunate because cancer drugs were inhibited and that is unfortunate" (author interview, senior faculty member, mouse genetics).

According to observers, "the grumbling reached insurrection proportions after a meeting at Cold Spring Harbor" in August 1992 (Anderson 1993, p. 23). In an impromptu session, over 300 researchers stayed on to share their grievances and plot potential strategies for resistance. The most immediate response came from JAX director Ken Paigan, who spontaneously, and without prior consent of his own legal counsel, offered to distribute the OncoMouse. His statement gave JAX legal counsel headaches for years to follow, but his commitment to exchange signaled to other researchers that they too might resist DuPont, even in the face of criticism by their universities. The long-standing sense of community and community organizations allowed mouse geneticists to confront DuPont by mobilizing their most powerful institutions to pressure the company. Their leading journal, *Science*, published editorials and articles on the controversy, issuing stinging critiques of DuPont. Scientists had made progress defending their boundaries and exchanges from invasion, but as Tyler Jacks, a leading MIT geneticist, put it: "The community's lobbying is a success story, to the extent that it's made an objectionable policy much more palatable. . . . But I'm still not convinced we've reached the optimal solution" (Anderson 1993, p. 23).

Act 4: Formal Compromise

Was the academic community at an impasse with DuPont? The firm insisted on asserting its IP rights and its right to craft commercial exchange strategies, while the mouse community insisted that commercial strategies had no place in academia. Harold Varmus (by then director of the NIH) opened formal discussions with DuPont in 1995 and personally visited senior corporate leaders, arriving informally dressed in the staid surroundings of the century-old corporation. After four years of protracted negotiations, DuPont and the NIH signed a memorandum of understanding (MOU) allowing researchers to freely exchange the OncoMouse as

long as they had a material transfer agreement (i.e., there were no reporting requirements and no reach-through rights; Smaglik 2000). One TTO commented on this change in strategy:

> I had a lot more PIs who wanted mice from JAX, but they were on hold until we signed the license. . . . This was really the point at which the business decision changed for us. We can now receive the mice from other academic institutions and send it to other academic institutions under a simple MTA. Nevertheless, there are still problems. They [DuPont] did not want us to send any mice we make that are covered to a company. We could do that but not for consideration [financial reward], which makes no sense if the company was willing to pay. (Author interview, TTO)

In the aftermath, DuPont's corporate intellectual property manager recognized the importance of academia's rights; now, DuPont "deeply appreciates the importance of wide dissemination of tools for basic research and is committed to making [its oncomouse] available to the academic community" (quoted in Marshall 2000, p. 567). Compromise was reached.

Behind the Scenes

If the narrative were to end right here, this account of the mouse genetics community would be a reasonably conventional institutional story of resistance and retreat: in defending their boundaries, scientists reaffirmed their commitment to autonomy and their traditional exchange practices. In response, commerce retreated, and the boundaries remained distinct. By looking behind the scenes, we find that the story is more complicated. One mouse geneticist remembers: "I was chairing yet another session on the problems of patenting in mouse models [the meeting took place at Cold Spring Harbor in the late 1990s]. . . . Everyone was complaining about the patent restrictions, what the licensing requirements were, how arduous they were and how they stopped them from acting independently. . . . Then I asked 'Would all those in the room with a patent please stand up?' Suddenly half the room stood up" (author interview, junior faculty, mouse genetics).

Many of the same mouse scientists who were furious at DuPont's licensing approach were now patenting their own work. In the decade after the OncoMouse patent, mouse geneticists, including all the leading scientists who had developed transgenic mice in the early 1980s, had filed (and were granted) patents on over 110 transgenic mice designed to mimic diseases from Alzheimer's to Kaposi's sarcoma, on the use of transgenic mice, and on research tools related to their production. Explaining the origins of this apparent hypocrisy can help in understanding the complex

boundary work arising when two powerful institutions collide and give us a deeper appreciation for the processes that produce hybrid exchanges and the meanings they embody. Thus, Section IV revisits the hybrid strategies used by scientists as they responded to the oncomouse controversy and more fully explains the link between the characteristics of hybrids and their implications for overlapping logics.

IV. ANALYZING HYBRID EXCHANGE STRATEGIES—MEANING AND BOUNDARIES

Traditional Explanations—Hostility, Blending, Coexistence

The literature on overlapping institutional logics posits three alternative perspectives on the rapid patenting activity of mouse geneticists: hostile worlds, blended worlds, and coexisting logics. "Hostile worlds" predicts that as patents take hold, the academic logic constructed through its exchange strategies will be replaced with commercial ones. However, we can reject this explanation in the circumstances surrounding oncomice. While academic exchange strategies were more contentious than in previous periods, and competition was intense, the exchange of knowledge and mice for prestige, reputation, and collaboration continued. In the "blended worlds" view, we would expect that the academic and commercial communities of mouse genetics would seamlessly blend with new hybrid exchanges, reflecting an emerging blended logic. However, the tension between DuPont and academics makes this implausible. Scientists expressed their outrage in public meetings and the scientific press. Some attempted an alternative—to discourage their students from joining DuPont. Of course, the supply of well-trained life scientists did not dry up at DuPont, but some of the leading laboratories were less connected to DuPont's own fledgling biotechnology activities in this period. Furthermore, few leading mouse scientists crossed the commercial-academic boundary (in either direction), suggesting that, for people, at least, distinctions were not blending.

The concentration of patenting among only the most senior mouse geneticists also suggests that patenting was not an action that might easily be incorporated into the tool kits of more junior faculty and was therefore not integral to academic exchanges, nor had a blended reward system emerged.

The third perspective—coexisting logics—anticipates that mouse geneticists, realizing the economic value of patents, would file patents and use them only as the basis for commercial exchanges such as licensing. However, scientists' lived experience of patenting was fraught with tension, and role conflict was significant (Merton 1957); their actions cannot

therefore be explained as easily as the strategies of museum professionals simultaneously supporting the conflicting goals of curatorship and education, which DiMaggio describes as emerging from different roles (1991, p. 285). Moreover, the entire OncoMouse episode reminded scientists that, once licensed, patents could be damaging to academic exchanges, and commercial exchanges could not easily be confined to the commercial sphere. Furthermore, the scientists now patenting also worked hard to spoil the commercial market for transgenic mice for DuPont and for all subsequent patent holders on mice as research tools and methods. The agreements with DuPont reduced the economic value of any patent and made it difficult to launch a viable business around research tools. Why then did mouse geneticists patent? How did they incorporate patents into hybrid exchanges? And what can we learn from this about the mechanisms through which hybrids are produced and in turn shape overlapping institutional logics?

Alternative Interpretation—Reinforcing Distinction by Shaping Meaning

Although patents were a source of conflict for mouse geneticists, in the decade after the OncoMouse patent, many scientists learned how to acquire patents for their work; they studied the language of contracts and sought to understand the resources that provided the foundation for the commercial exchange strategies. Concerned with DuPont's actions, most of the scientists interviewed (predominantly those with high status in the community) approached lawyers (typically acquaintances rather than formal legal counsel) to learn the details of patent law so that they could understand the precise limits of the property rights. Scientists also gained a more sophisticated understanding of the law from one another in vigorous debates at scientific gatherings, from private conversations, and from their TTO officers. As one lawyer noted, "It was as if they were finally waking up to the fact that the law could be useful and patents were more than just pieces of paper you filed in some office with an expensive lawyer in a suit."

Most had started the post–Bayh-Dole era with a naive view of patents, and some voiced surprise over Leder's initial decision to patent: "He took out a patent much to the shock of the rest of us. Anyone who makes any kind of mouse is financially beholden to Phil, and that was a very odd situation" (author interview, senior scientist). Other researchers sympathized with Leder, describing this situation, and the similar events in knockout mice, as an unintended consequence of patenting. One interviewee, showing a nuanced understanding of how patents are adjudicated and used, "wouldn't criticize Leder because my concern is breadth [of the

patent] and that is a U.S. Patent Office decision. I also fault DuPont for their interpretation of the claims and their business practices" (author interview, senior scientist in embryology). Like Leder, these scientists believed that patenting was an obligation under the recent Bayh-Dole Act. Several scientists I interviewed confirmed that, like Leder, they too thought of patenting decisions in unproblematic terms until the OncoMouse incident: "One of the elements of the creation of these mice—these animal models of human disease—was that it coincided with a time that the Supreme Court had just decided that life forms could be patented. And as an obedient employee of Harvard Medical School, Tim and I reported this invention to our Office of Technology Licensing as an invention and a discovery, which we disclosed to them and which potentially would be patentable. They consulted with a patent attorney and it was patented" (Leder, quoted in Lasker Foundation 1987).

Any fault, scientists argued, lay with Harvard for "naive licensing" or with DuPont for "aggressive practices that clearly misunderstood the nature of academia" (author interview, senior scientist in genetics). Nonetheless, armed with their newly acquired legal knowledge, several scientists tried sitting down with DuPont, and explaining their position and their own interpretation of what they considered the appropriate scope of the patent as a means of challenging the exchange strategies DuPont had in mind: "I objected to the license on the grounds that DuPont's interpretation of the patent was too broad. In their view it covers any germline manipulation of the mouse. I sat with their lawyer who told me this was all about enablement . . . I am not sure about that but what I do know is that the claims have never been challenged. I explained my view of the appropriate claims and won't sign anything for uses beyond that. They told me 'you are in violation of the law' so there you are" (author interview, leading scientist in mouse genetics).

Taking an approach to reshaping exchange more commonly found in the commercial sphere, scientists tried to use the legal system to bring a lawsuit to invalidate or narrow the scope of the patent in the hopes of obviating or at least limiting their powerful commercial resources. But this approach received a mixed response: "I have been contacted over the years by two or three lawyers on behalf of other academic labs who wanted me to join them to challenge the patent so that they could avoid the licenses and void the patent. I didn't join them—it just seemed like an exercise that would be costly and time consuming. I preferred to get on with what I was doing, breed my mice and ignore the patent" (author interview, senior scientist in embryology).

Another said, "I wish there had been a suit filed against DuPont but I am afraid if you do the calculation of how much that would cost compared to the one or two million dollars the license might cost a firm, it's good

business strategy not to sue, and no university will take this on" (author interview, senior scientist in cancer biology). These actions never gained adequate momentum, but they gave scientists deep insights into the control and flexibility embodied by patents and the licensing contracts built around them. Consequently, they began to patent their own work. Superficially, this seems hypocritical until one examines the exchanges they were crafting. Mouse geneticists were building hybrid exchanges that used patents (and contracts based on property rights) to prevent industry encroachment, not encourage it, and to use industry to reinforce the academic logic. To do so, they used the property rights inherent in patents to defend the academic-commercial boundary and worked to transform the meaning of patents.

Three strategies emerged: patents were used as (i) resources for protecting the scientific commons, (ii) foundations for a new "social order" at the academic-industry boundary, and (iii) the basis for incentives to transfer research tools into industry in the hope that the tools would be more rapidly adopted in academia. In these three strategies, patents were primarily used as tools for promotion of scientific objectives and expansion of scientific communication, not as a defense against use of scientific knowledge. Whereas DuPont had exercised its IP rights to derive economic rents from a valuable asset, the academics deliberately stripped many of the direct economic implications from their patents. The new meanings allowed academic scientists to further the traditional aims of academic science and use hybrids to strengthen distinction.

Patents as Resources for Protecting the Scientific Commons

The boundary skirmishes over the OncoMouse made many mouse geneticists much more sophisticated about the nature of academic publications as a form of public commons, and the role of intellectual property in both encroaching on and protecting the commons. Many geneticists cited Heller and Eisenberg's 1998 *Science* essay as providing a powerful image of a public commons that they felt should be protected (ironically, the article argued that the commons was doomed). However, some mouse geneticists recognized that patents were not only useful in defending ideas from encroachment by others (i.e., the commercial strategies traditionally pursued by firms who hold property rights). Rather, academics found that they could use patents to exclude the excluders—thwarting unwanted commercial interests and, more important, preventing themselves from being excluded—to establish a commons. Thus, as they learned about the law, mouse geneticists imbued patents with a new symbolic status—a resource to protect, not exploit, the scientific commons (a strategy later employed effectively in the software arena) and thus a

means to support the academic logic, not undermine it. In interviews, the plight of Palmiter and Brinster often arose as a touchstone in explaining this strategy. The two scientists had developed the earliest transgenic mice, eventually inserting an oncogene into a single egg to create an oncomouse, around the same time as Leder's lab. Both teams received equal academic "credit" for their work by Harold Varmus (1993) in his Nobel Prize speech. Yet, the patent allowed for no such multiples. Palmiter and Brinster were subject to Harvard's patents. Their research did not trump the Leder patent because they had not filed for patents, and they would not bear the costs of a lawsuit establishing the priority of their own research. Not surprisingly, they were among the first in the mouse community to file patents in the following years as a protective measure, and others followed their lead. One geneticist described his approach in terms of the commercial language of "defensive patenting" (although in fact that strategy is used by the patentor to exclude others, while the academics were trying to prevent themselves from being excluded): "We really struggle with patenting decisions. We want our stuff to get out and we want people to use it so we often choose to avoid patenting but on the other hand at times we decide to patent defensively. I mean if we are doing a series of experiments and we develop some methods, we don't always describe them in detail in the publications so at least in theory someone else could come along and patent and scoop us and then we wouldn't even be able to use our own stuff. I am sure that's how the early transgenic guys felt" (author interview, leading geneticist).

Other geneticists traced their decision to patent directly to the idea of keeping commercial interests from controlling the public commons in science. A scientist explained: "I did take out a patent once, but not for a mouse, for a method. Why? Well frankly to keep any number of companies from using the technique and making money doing that. I didn't want any company to make money doing that and I didn't want to make money myself" (author interview, senior scientist in embryology).

The decision to publish also took on new meaning. Prior to the rush to patent, publication was a reflexive phenomenon. If one had results, one published. With patenting opening up as an avenue for disclosure, scientists came to better understand publishing. A publication was seen as a public good, a quasi-protest against patents, or, at the very least, a comment on what should be in the scientific commons. In this view, individual prestige was combined with a public notion of dissemination. "I think that when we look back at some of these major academic projects and the way in which they have rubbed up against industry we will realize that industry forced us to think and reflect about what it means to disclose and share. These situations have challenged us to be more public and less competitive with our work and so perhaps in the long

run they have been good for science" (author interview, junior scientist in mouse genetics).

Patents as Foundations for a New "Social Order" at the Academic-Industry Boundary

Mouse geneticists found that patents were a useful resource and rhetorical device in creating clarity and "social order" at the academic-commercial boundary. Patents emerged as a way of clarifying relations with commercial concerns and extracting appropriate exchanges with industry. One patent lawyer commented that "scientists were reinventing the entire area of patent and contract law for themselves—eventually they came to see that patents could actually be useful to them" (author interview). Patents provided a clear delimitation of ownership, but the strict legal notions of inventorship also allowed scientists to define the contribution of an inventor and the rights associated with a particular invention. One scientist noted: "At least we know who owns what, who invented what. . . . Industry always tries to get on our publications, in fact they even tried to write that into our sponsored research agreement—what nerve. But they don't try and do that over patents, and so that really helps us keep everyone honest" (author interview, junior scientist in molecular biology)

Patents clarified the issue of ownership, defined the boundaries of collaboration, and spelled out how issues of control could and should be exercised. Academics frequently expressed disappointment about their contacts with industry. Remarks such as "funding suddenly dried up," "when the new person came on board we were no longer relevant," and "at times they seem to just walk off with our ideas" were typical in interviews. When patents were at stake, academic scientists could engage in differentiated exchanges with commercial scientists more easily. Negotiations over authorship could still focus on the subtle bargains and expectations of academia, while academic-industry relationships could focus on inventorship, mediated by lawyers.

Over time, the mouse community built up a repertoire of rich, commercially oriented legal arrangements that included patents but extended to MTAs, research contracts, and other legally based arrangements. Not surprisingly, given the aggressive actions of commercial actors in mouse genetics, boundary work at the academic-industry nexus was increasingly associated with the logic of commercial science to such an extent that some firms complained about the legalistic and market-oriented nature of academic exchange. In this process, not only mouse geneticists but also other members of the university, including TTO officers, legal counsel, department chairs, and research officers, became increasingly sophisticated in their use of patents and other commercial mechanisms to structure

local order. And one veteran TTO officer said: "We don't usually patent a mouse model anymore. Times have really changed. We can normally license a mouse model nonexclusively to a company and get over $10,000 even without a patent because we have the model. It takes a lot of work, and validation to have a published and accepted model and so we don't need to patent. We can patent but we can't make money out of it. But every institution has had to sit down to figure this out" (author interview, TTO).

In the course of figuring this out, the dominant arrangement at the boundary shifted from exchanges where ideas around mouse genetics flowed unfettered over the boundary, to one structured by contracts and based on more distributive bargaining (Bacharach et al. 1996) between academia and industry. This new arrangement more closely followed the commercial logic of property rights as a means of ordering, allocating, and exchanging resources (Alchian and Demsetz 1973), but in the hands of the mouse scientists (although not necessarily other actors within the university), these hybrids were structured to reinforce the academic logic.

Patents as Tools for Reinforcing the Academic Logic

Using the inherent flexibility in patents, academic scientists developed a complex new repertoire of exchanges with industry as a means of generating and reinforcing academic rewards. Mouse geneticists recognized the potential of property rights for reinforcing the commercial logic. However, they also (more subtly) recognized that in doing so, patent-based exchanges might potentially provide academic scientists with more scientific credit and therefore marshal industry's resources to enhance the strength of the academic logic. Many scientists talked about the role of patents in getting a product into the hands of patients and disseminating it to researchers. "I haven't used patents very much but I think they are a necessary evil. I mean I think we all know by now that you need them to get industry interested in what you do. The way I think about it is to ask the question: Is it worth spending the money to patent? If I think that industry will only use it if there is a patent, and if it's really important then fine, let's go ahead" (author interview, junior scientist in mouse genetics).

Mouse geneticists recognized that through the careful use of patents, industry could be co-opted into making further investments in scientific ideas. This fulfilled a sense of obligation many held—that their "research has a long term impact on health, on diseases like cancer, and on finding a cure" (author interview, senior scientist in mouse genetics)—and ensured that their ideas were widely available. One TTO officer outlined the logic: "Most of our scientists really want their ideas to be developed and es-

pecially if they have new tools they realize that industry can play an essential role in making these tools more stable, better validated and more easily available. When this happens, they get the satisfaction of seeing their work much more widely disseminated in academia as well as industry" (author interview, TTO).

While this was counter to their experience with the OncoMouse, mouse geneticists felt that with more carefully crafted ordering across the boundary and through more sharply drawn distinctions, new exchanges with industry, based on patents, would allow academics to further their traditional rewards of prestige and reputation.

Many scientists recognized that patents rewarded firms that build scientific tools (they just objected to the way those firms went about reaping those rewards). Therefore, patenting for some became a form of strategic disclosure designed to move their ideas into widespread circulation by alternative routes, thus reinforcing the academic logic of ensuring that one's ideas were as widely known and accessible as possible. Leder noted:

> I remember it used to be the policy at the National Institutes of Health—it no longer is—but to pursue patents on their discoveries, and then to dedicate the patent to the public domain. Now that sounds terrific. What could be better than that? The government has achieved a patent, and it has then dedicated it to the public domain so anybody can use that. The problem with that, as I have encountered it, was that nobody was interested. Unprotected by patents, nobody was ready to make the investment in the utilization of that technology. I wish the world were different, but that is what it seems to be like. NIH has changed that policy and that has made a tremendous difference, because I think in no field has there been a more dramatic change in transferring technology to the public good than there has been in biology over the last 20 years. (Lasker Foundation 1987)

Institutional Support of Hybrid Exchanges

What was challenging about these new practices was making the careful calculation over when something should be patented to allow for hybrid exchanges that reinforced the academic logic and when patents might have unintended consequences that scientists could neither predict nor control. More than a few mouse geneticists confessed that differentiation was a delicate balance that was complex to manage, and the impact of different choices hard to anticipate: "I suppose I should have a better philosophy about what I patent. I think that enabling materials should have broad access and you could argue that any price is too high for these materials. We rarely patent—we mainly choose a number of nonexclusive licenses, and we are given the leeway by the university to do that, but

these are subtle and complex decisions. Are we the best people to make them? Probably not" (author interview, leading scientist in molecular biology).

In direct response to the DuPont experience and to the challenges that every individual scientist confronted in determining the most effective hybrid strategies to pursue, the wider academic science community and its most powerful organizations stepped in to reinforce the academic logic and ensure that patents strengthened the salient distinctions between academia and industry rather than undermined them. In the whirlwind of controversy around licensing of transgenic and knockout mice, the NIH and leaders like Varmus reconsidered their role in the dissemination of research. In 1999, the NIH released guidelines for the patenting of research tools (Marshall 1999) that underscored the lessons Varmus learned from the OncoMouse. Several years later they released broader guidelines for all forms of sharing that went well beyond tools. While seen as a positive step by academics, the tension at the academic-industry boundary was obvious in the words of a biotech executive describing the changes as an "unmitigated disaster" (Marshall 1999).

Under pressure from academic scientists who often used the OncoMouse as a touchstone, TTO professionals also started to adapt their support of scientists' exchange strategies. Most U.S. universities incorporated licensing clauses that provided a research exemption, at least to an inventor and his or her university. The Association of University Technology Managers (AUTM) engaged its members in widespread discussions of transgenic mice licensing, led by Joyce Brinton (head of the TTO at Harvard at the time of the OncoMouse license) and Irene Abrams at MIT, who had extensive experience with another transgenic mouse (see Abrams and Kaiser 2000). As a result:

> There are new guidelines from AUTM and we try and say to companies that we follow the NIH guidelines for research tools. So in general, we do not do exclusive licenses for tools any more. The early licenses were not like this and so Harvard would have had no choice in the way they set up their sponsored research with DuPont. Now we have changed so that we keep the rights to use any research tools and disseminate them through a non-exclusive and also have academic exemptions. If it is exclusive we try to put the language in that our scientists have the right to continue to do research, but at times there may be push back. Not every TTO can do this, especially smaller institutions. We always try to make sure that there are exemptions, due diligence terms to try and avoid cases like the oncomouse. (Author interview, leading TTO officer)

V. DISCUSSION AND CONCLUSIONS

While sociological analyses of institutional logics have emphasized the importance of boundaries and hybrid practices arising at boundaries, they have devoted less attention to the link between properties and mechanisms at boundaries (Lamont and Molnar 2002), and the processes at work as these complex zones of overlapping logics emerge (Lounsbury 2007; Schneiberg 2007). The oncomouse case provides a dynamic window into one such complex zone, emphasizing as it does the limits of assuming that hybrids only arise as boundaries "dissolve to produce hybridity" (Lamont and Molnar 2002, p. 189) or collapse. It also emphasizes continuing tension aimed at maintaining distinction between worlds instead of a comfortable coexistence. By examining social action at the boundary over time and across a specific moment at the boundary—in the period just prior to and after a significant perturbation—the case illustrates that hybrids can arise from and maintain distinction between two logics. These findings have important implications for scholars of boundaries and hybrids across a wide variety of settings. The temporal dynamics exposed during the analysis also provide insights into the nature and conditions of institutional change.

Worlds in Productive Tension—a New Lens on Hybrids and Boundaries

Beyond the world of mouse genetics, the oncomouse case has implications for our conceptual understanding of hybrids and overlapping institutional logics. The prior literature on boundaries takes a number of different perspectives on hybrids and the mechanisms that produce them. Many studies have described the mixing of resources from different logics, including transposition (Sewell 1992), synthesis (Chen and O'Mahony 2006), layering (Thelen 2004), and blending (Rao et al. 2005), but the link between properties and mechanisms at boundaries is disputed. On the one hand, scholars have argued that hybrids are a product of collapse or blending—the hostile worlds and blended worlds perspectives. On the other hand, some focus on the stability of hybrids; they are a fact of institutional life and symbolic of the comfortable everyday coexistence. The OncoMouse case reconciles these contradictions by emphasizing that distinct worlds do exist even when hybrids are observed but that these distinctions exist in a sort of productive tension. It also highlights that while an exogenous shock might be the impetus for institutional change and provide resources for hybrids, hybrid exchanges themselves are produced through the actions of participants (Heimer 1985). A few key actors operate in a manner akin to institutional entrepreneurs (DiMaggio 1988;

Fligstein 1997) and define the productive tension at the institutional boundary and the hybrids that emerge from it. In doing so, they bring together a rich set of rules, resources (Sewell 1992), and property (Stark 1996) and combine them to become sophisticated producers of new hybrids. Central to their production of these boundary-reinforcing hybrids is the expertise gained by key actors; expertise that allows them to transpose elements from each logic into exchanges that reinforce difference rather than diminish it. In building their expertise, these actors do not produce hybrids in isolation. Rather, they develop complex new sets of social relationships with parties that are not usually participants in their social life (Johnson 2007). For scientists, this meant working with lawyers, TTO professionals, university counsel, and corporate executives. By elaborating the ways in which a productive tension is established at institutional boundaries, this work not only elaborates on an important feature of hybrids but provides a deeper understanding of their production.

Beyond the science-market interface, a number of other worlds also maintain distinction through hybrids. For example, software communities founded on the basis of the free software movement, "copyleft" provisions for exchange, and widespread sharing and elaboration of code can and do come to produce hybrid exchanges with for-profit software firms (O'Mahony 2003). When these two communities come together, there is no imminent collapse, nor do they become blended. However, their boundary is far from comfortable. Instead, the two worlds exist in a productive tension engaging in highly contested boundary work to establish a boundary zone where software can be created but where distinctions remain salient. By transforming the traditional tropes of the market—copyright, governance, membership—into resources that can reinforce the open source community, software developers have established hybrid exchange strategies that produce resilience (Murray and O'Mahony 2007). They have also produced hybrid boundary organizations as a locus for the continued management of the productive tension and the opportunities it affords (O'Mahony and Bechky 2008).

Insights into Institutional Change

How can we resolve the notion of distinctive worlds in productive tension with the many prior studies showing that some boundaries do indeed collapse or blend (Powell 1985; Thornton 2002; Rao et al. 2005), leading to a dramatic reshaping of the institutional landscape? This study suggests an important restatement of our studies of hybrids and their role in institutional change; rather than ask how boundaries dissolve to produce hybrids and collapse, we should instead ask under what conditions are hybrids produced from productive tension to maintain distinction and

under what conditions are they produced from blending to reduce distinction (see also Westphal et al. 1997; Van de Ven and Hargrave 2004).

If we take as a given that institutional overlaps are rich in the raw materials required for complex strategies of action (Sewell 1992), then three conditions seem particularly salient in transforming these resources into a source of productive tension and a means to reinforce boundaries and highlight distinction. First, the opportunities for hybrids to arise from productive tension will be most dramatic when the dominant exchange strategies have inherent flexibility. While this is true of many exchanges, academic exchanges and those built around patents were underdetermined, and the law is flexible (Ewick and Silbey 1998), allowing skilled actors considerable leeway to take and transform exchanges and shape the meaning of the resources they put to work. When meaning is rigidly prescribed, opportunities for transformation through social action become more limited, as might be the case if universities were to replace tenure with corporate-style employment contracts. Second, the institution under threat was secure, and commercial encroachment was just that, not a bid for total control. To be more specific, we might speculate that the production of hybrids to reinforce boundaries arises when actors feel that an important ideology is threatened, but not that their jobs, livelihood, or really even their status are threatened. Third, prior social structures and organizations provide an important scaffold for the types of social action that lead two worlds into productive tension (Padgett and Ansell 1993; Suddaby and Greenwood 2005). Scientists relied upon established meetings such as Cold Spring Harbor to collectively air their grievances and describe their strategies. Ties to powerful organizations such as the NIH, the AUTM, and journals contributed to their ability to reinforce their individual actions with collective action that became institutionalized. The well-established social structure of mouse genetics also provided another source of power as it buffered those engaged early on in producing hybrid exchange strategies from the potential criticisms of their peers. Their status was sufficiently secure within their communities and universities that they could transgress previously taken-for-granted norms in the search for hybrid exchanges that would strengthen the academic logic and resist DuPont.

By articulating the possibility that hybrids can exist in productive tension at the boundary of overlapping logics, and that they serve to defend and reinforce institutional distinction, this study questions the basic premise that hybrids presage blending, collapse, or coexistence. From a normative perspective, this finding should assuage some of the concerns of sociologists who worry that "realms that used to be tempered by extra-market norms and institutions are now being marketized with accelerating force" (Kuttner 1997, p. 55, quoted in Zelizer 2005). Finding evidence of

commercial exchanges all around them, scholars have characterized economic forces as capturing and corrupting institutions, social structures, and practices previously defined by an alternative logic of action. This study suggests that some institutional logics can exist in a productive tension with the market logic (or other logics) rather than collapsing. That they can do so speaks to the power of institutions to shape meaning.

Patents are social constructions forged in the realm of the market. When this social construction is transplanted into a different institutional logic, the context shifts, and meanings can be transformed (Thelen 2004). Armed with new meanings, actors can forge a richer repertoire of hybrid exchanges and use them to defend their boundary and reinforce their logic. Beyond the normative implications, through a deeper examination of hybrids as they are produced through social action, this article steers a path through contradictory perspectives on hybrids, arguing that a resolution can be found in the production of hybrids out of attempts to defend boundaries and reinforce logics. Based on this insight, research on hybrids can progress beyond mere description to an understanding of the dynamics of hybrid formation, distinguishing among conditions of collapse, blending, coexistence, and distinction. A more profound understanding of these dynamics should lead to further insights into the stability and evolution of hybrids occurring in other social contexts where institutions overlap.

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