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In a number of technologically advanced industries, a new logic of organizing is developing. Rather than viewing firms as vehicles for processing information, making decisions, and solving problems, the core capabilities of organizations are based increasingly on knowledge-seeking and knowledge-creation. In technologically intensive fields, where there are large gains from innovation and steep losses from obsolescence, competition is best regarded as a learning race. The ability to learn about new opportunities requires participation in them, thus a wide range of interorganizational linkages is critical to knowledge diffusion, learning, and technology development. These connections may be formal contractual relationships, as in a research and development partnerships or a joint venture, or informal, involving participation in technical communities. Both mechanisms are highly salient for the transfer of knowledge and are reinforcing. Yet even though the awareness of the importance of both external sources of knowledge and external participation has grown, we know much less about how knowledge is generated, transferred, and acted upon in these new contexts.

The Twin Faces of Collaboration

By a variety of accounts, the number and scope of interorganizational collaborations have grown rapidly in many industries, most notably in the field

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of biotechnology.[1] In the world of practice, this heightened interest is captured in discussions of the "virtual firm," and evidenced in all manner of cooperative relationships that join two or more organizations in some form of common undertaking.[2] In the world of theory, research on various forms of collaboration has two principle foci: on the transaction and the mutual exchange of rights; and on the relationship and the mechanisms through which information flows and mutual adjustments take place. Typically, the more exchange-oriented analysis treats collaboration as a variant of the make or buy decision and analyzes key features of the transaction: how it is negotiated and which party retains what control rights.[3] Thus, it matters a great deal whether common assets are being pooled or different resources traded, what stage of development a project is at, and whether some form of ownership is involved.[4] This strand of research, based primarily in the fields of industrial organization economics and business strategy, focuses more on the contractual mechanisms for coordinating interorganizational relations.

The second line of inquiry, stemming more from sociology and organization theory, adopts a processual focus, analyzing whether features of the task require continuous communication and organization learning, and the extent to which the collaboration is embedded in multiple, ongoing relationships.[5] This approach focuses on the relational capability of organizations, how and when organizations are able to combine their existing competencies with the abilities of others. These capabilities are not viewed as static, but rather emerge and deepen over time as firms both develop existing relationships and explore new ones.

These two perspectives are, at times, viewed as competing explanations, but since they involve different units of analysis—the transaction and the relationship, respectively—they need not be. Key structural features of an industry may determine the relative weight that contractual and processual elements play in interorganizational collaborations.[6] Large-scale reliance on interorganizational linkages reflects a fundamental and pervasive concern with access to knowledge. In the rapidly-developing field of biotechnology, the knowledge base is both complex and expanding and the sources of expertise are widely dispersed. When uncertainty is high, organizations interact more, not less, with external parties in order to access both knowledge and resources. Hence, the locus of innovation is found in networks of learning, rather than in individual firms. How contracts are structured is not unimportant; in fact, getting the intellectual property rights specified clearly is critical. But focusing too closely on the transactional details of an exchange risks missing the boat as the larger field rides the waves of rapid technological change. Moreover, current work on contractual aspects of collaboration between biotech and pharmaceutical firms suggests that as the relationships unfold, many of the specific covenants contained in contracts are not invoked.[7] In short, process matters, and firms differ in their ability to do relational contracting.

In several key respects, arguments about the learning and strategic aspects of collaboration converge to produce new questions about the pivotal role of learning and interfirm relationships in rapidly developing industries. Firms in technologically intensive fields rely on collaborative relationships to access, survey, and exploit emerging technological opportunities. As the structure of an industry becomes shaped by interorganizational relations, the nature of competition is altered, but the direction of change is very much open. First, collaboration raises entry barriers. To the extent that the capabilities of organizations are based in part on the qualities or capabilities of those with whom they are allied, collaboration increases the price of admission to a field. If parties act either opportunistically or restrictively, collaborating only with a narrow range of partners whose behavior they can influence, then collaboration can exclude admission to many. But if the participants interact broadly and engage in mutual learning with the organizations they are affiliated with, the effects of collaboration are expansive, mobilizing resources throughout a field, with collaboration serving as an inclusive entry pass. Second, interfirm cooperation accelerates the rate of technological innovation. In our earlier work, we demonstrated a ladder effect, in which firms with experienced partners competed more effectively in high-speed learning races.[8] Rather than seeking to monopolize the returns from innovative activity and forming exclusive partnerships with only a narrow set of organizations, successful firms positioned themselves as the hubs at the center of overlapping networks, stimulating rewarding research collaborations among the various organizations to which they are aligned, and profiting from having multiple projects in various stages of development.

Third, reliance on collaboration has potentially transformative effects on all participants. Those positioned in a network of external relations adopt more administrative innovations, and do so earlier.[9] The presence of a dense network of collaborative ties may even alter participants' perceptions of competition. Inside a densely connected field, organizations must adjust to a novel perspective in which it is no longer necessary to have exclusive, proprietary ownership of an asset in order to extract value from it. Moreover, since a competitor on one project may become a partner on another, the playing field resembles less a horse race and more a rugby match, in which players frequently change their uniforms.[10] Seen from this perspective, decisions that were initially framed as strategic have cumulative consequences that alter the economic calculus, while choices motivated by learning and experimentation remake the institutional landscape.

Finally, collaboration may itself become a dimension of competition. As firms turn to outside parties for a variety of resources, they develop a network profile, or portfolio of ties to specific partners for certain activities. Thus, for example, an emerging biotech company may have a research grant from a branch of the National Institutes of Health, a research collaboration with a leading university, licensing agreements with other universities or nonprofit research institutes, clinical studies underway with a research hospital, and sales or

distribution arrangements with a large pharmaceutical corporation. Others may have only one such relationship, or may hook up with the same partners for different activities, or with disparate partners for similar activities, or have complex relationships involving multiple activities with each partner. Analytically, each combination of partnership and business activity represents a distinct collaborative relationship. A firm's portfolio of collaborations is both a resource and a signal to markets, as well as to other potential partners, of the quality of the firm's activities and products. Whether firms in a field are constrained to a narrow set of relationships or have broad options in determining their portfolios has profound consequences for competition. To draw on the language of political sociology, heterogeneity and interdependence are greater spurs to collective action than homogeneity and discipline.[11] If the members on an industry are constrained in their choice of partners to a small set of potential partners, competition is increased, but within a narrow sphere. The effect is like a tournament, in which the "winners" receive exclusive sponsorship in order to compete against each other in ever-fiercer rounds. On the other hand, if there is a broad and growing set of nonexclusive partners, then the participants will evince heterogeneous collaborations, and the avenues of rivalry are widened.

In sum, regardless of whether collaboration is driven by strategic motives, such as filling in missing pieces of the value chain, or by learning considerations to gain access to new knowledge, or by embeddedness in a community of practice, connectivity to an inter-organizational network and competence at managing collaborations have become key drivers of a new logic of organizing. This view of organizations and networks as vehicles for producing, synthesizing, and distributing ideas recognizes that the success of firms is increasingly linked to the depth of their ties to organizations in diverse fields. Learning in these circumstances is a complex, multi-level process, involving learning from and with partners under conditions of uncertainty, learning about partners' behavior and developing routines and norms that can mitigate the risks of opportunism, and learning how to distribute newly acquired knowledge across different projects and functions. But learning is also closely linked to the conditions under which knowledge is gained, and in this sense the motives that drive collaboration can shape what can be learned. Much sophisticated technical knowledge is tacit in character—an indissoluble mix of design, process, and expertise. Such information is not easily transferred by license or purchase. Passive recipients of new knowledge are less likely to fully appreciate its value or be able to respond rapidly. In fields such as biotechnology, firms must have the ability to absorb knowledge.[12] In short, internal capability and external collaborations are complementary. Internal capability is indispensable in evaluating ideas or skills developed externally, while collaboration with outside parties provides access to news and resources that cannot be generated internally. A network serves as the locus of innovation in many high-tech fields because it provides timely access to knowledge and resources that are otherwise unavailable, while also testing internal expertise and learning capabilities.

The Network Structure of the Biotechnology Field

The science underlying the field of biotechnology had its origins in discoveries made in university laboratories in the early 1970s. These promising breakthroughs were initially exploited by science-based start-up firms (DBFs, or dedicated biotechnology firms, in industry parlance) founded in the mid to late 1970s. The year 1980 marked a sea change with the U.S. Supreme Court ruling in the Diamond vs. Chakrabaty case that genetically engineered life forms were patentable. And Genentech, which along with Cetus was the most visible biotech company, had its initial public offering, drawing astonishing interest on Wall Street. Over the next two decades, hundreds of DBFs have been founded, mostly in the U.S. but more recently in Canada, Australia, Britain, and Europe.

The initial research—most notably Herbert Boyer and Stanley Cohen's discovery of recombinant DNA methods and Georges Köhler and Cesar Milstein's cell infusion technology that creates monoclonal antibodies—drew primarily on molecular biology and immunology. The early discoveries were so path-breaking that they had a kind of natural excludability, that is, without interaction with those involved in the research, the knowledge was slow to transfer. But what was considered a radical innovation then has changed considerably as the science diffused rapidly. Genetic engineering, monoclonal antibodies, polymerase chain reaction amplification, and gene sequencing are now part of the standard toolkit of microbiology graduate students. To stay on top of the field, one has to be at the forefront of knowledge-seeking and technology development. Moreover, many new areas of science have become inextricably involved, ranging from genetics, biochemistry, cell biology, general medicine, computer science, to even physics and optical sciences. Modern biotechnology, then, is not a discipline or an industry per se, but a set of technologies relevant to a wide range of disciplines and industries.

The commercial potential of biotechnology appealed to many scientists and entrepreneurs even at its embryonic stage. In the early years, the principal efforts were directed at making existing proteins in new ways, then the field evolved to use the new methods to make new proteins, and now today the race is on to design entirely new medicines. The firms that translated the science into feasible technologies and new medical products faced a host of challenges. Alongside the usual difficulties of start-up firms, the DBFs needed huge amounts of capital to fund costly research, assistance in managing themselves and in conducting clinical trials, and eventually experience with the regulatory approval process, manufacturing, marketing, distribution, and sales. In time, established pharmaceutical firms were attracted to the field, initially allying with DBFs in research partnerships and in providing a set of organizational capabilities that DBFs were lacking. Eventually, the considerable promise of biotechnology led nearly every established pharmaceutical corporation to develop, to varying degrees of success, both in-house capacity in the new science and a portfolio of collaborations with DBFs.

Thus the field is not only multi-disciplinary, it is multi-institutional as well. In addition to research universities and both start-up and established firms, government agencies, nonprofit research institutes, and leading research hospitals have played key roles in conducting and funding research, while venture capitalists and law firms have played essential parts as talent scouts, advisors, consultants, and financiers. Two factors are highly salient. One, all the necessary skills and organizational capabilities needed to compete in biotechnology are not readily found under a single roof. Two, in fields such as biotech, where knowledge is advancing rapidly and the sources of knowledge are widely dispersed, organizations enter into a wide array of alliances to gain access to different competencies and knowledge. Progress with the technology goes hand-in-hand with the evolution of the industry and its supporting institutions. The science, the organizations, and the associated institutions' practices are co-evolving. Universities are more attentive to the commercial development of research, DBFs are active participants in basic science inquiry, and pharmaceuticals more keyed into developments at DBFs and universities.

Nevertheless, organizations vary in their abilities to access knowledge and skills located beyond their boundaries. Organizations develop very different profiles of collaboration, turning to partners for divergent combinations of skills, funding, experience, access, and status. Biotech firms have not supplanted pharmaceutical companies, and large pharmaceuticals have not absorbed the biotechnology field. Nor has the basic science component of the industry receded in its importance. Consequently, DBFs, research universities, pharmaceutical companies, research institutions, and leading medical centers are continually seeking partners who can help them stay abreast of, or in front of, this fast-moving field. But organizations vary considerably in their approaches to collaboration. Put differently, some organizations reap more from the network seeds they sow than do others. Despite the efforts of nearly every DBF to strengthen its collaborative capacity, not all of them cultivate similar profiles of relationships, nor are all able to harvest their networks to comparable advantage. Similarly, not every pharmaceutical firm is positioned comparably to exploit the latest breakthroughs in genomics, gene therapy, and a host of other novel methodologies for drug discovery. A key challenge, then, for both small biotechnology firms and large global pharmaceutical corporations is in learning from collaborations with external parties, and in constructing a portfolio of collaborators that provides access to both the emerging science and technology and the necessary organizational capabilities.

Collaborative Portfolios

The various key participants in the biotechnology and pharmaceutical industries pursue different avenues of collaboration. A cursory study of the portfolios of key firms reveals distinctive mixes of alliances for different business functions. For example, in biotech, Amgen, a Los Angeles-based firm founded

in 1980, is often regarded as a bellwether for the industry. Amgen has extensive R&D and marketing collaborations with numerous small biotech companies, among them ARRIS, Envirogen, Glycomex, Guilford, Interneuron, Regeneron, and Zynaxis. These are relationships based on a division of labor in which the smaller firm develops promising technology with Amgen's financial and scientific assistance, and Amgen will market the eventual product. Amgen also holds several key licensing agreements with Sloan-Kettering Hospital (for a cell growth factor), the Ontario Cancer Institute (for knockout mice), and Rockefeller University (for an obesity gene). In contrast, Cambridge-based Biogen, founded in 1978 but with only 750 employees, adopted a strategy of licensing its initial research discoveries to such established firms as Abbott, Lilly, Pharmacia Upjohn, Merck, Organon Teknika, and Schering Plough. By 1996, Biogen's royalty stream had grown to $150 million annually. Biogen also outsourced the costly and time-consuming task of analyzing clinical trial data on its medicines in development to contract research organizations, but monitored the work with in-house experts.[13] Chiron, the largest biotech with more than 7500 employees, and 9 subsidiaries, is also partially owned by Novartis (49.9%) and Johnson and Johnson (4.6%). Chiron, founded in 1981, has the most extensive array of collaborations of any biotech with numerous R&D ties with smaller biotechs and universities, licensing agreements with large pharmaceutical and animal health companies, partnerships with larger biotechs, and manufacturing and marketing alliances with other large firms as well. Indeed, in a January, 1997 news release, Chiron reported that it now has more than 1,400 (informal) agreements with universities and research institutions and 64 (formal) collaborations with other companies. "This network is a core strength of Chiron," the release proclaims.

These different collaborative profiles reflect, in important respects, the mixed motives of strategy and exigency in the early years of building a company. Amgen works with younger, early-stage biotechs, but eschews close affiliations with many established pharmaceuticals. Biogen licensed out some of its initial research discoveries, and the substantial royalties it takes in now fund the development, sales, and distribution of Avonex, its successful drug for multiple sclerosis. Chiron has a spider-webbed universe of affiliations with basic scientists in universities, and it maintains ongoing ties with diverse biotechs and health-care companies. The partial "parent" owner, Novartis of Switzerland, appears to use Chiron as its window into this rapidly developing field.

Similarly, in the pharmaceutical industry, divergent approaches to collaboration are pursued. By the accounting of Recombinant Capital, a San Francisco company that tracks high tech, the big pharmaceutical firms poured $4.5 billion into deals with biotech companies in 1996.[14] Their aim is to capitalize on promising technology and the skills of the nimbler small companies in doing more rapid development. But dominant firms pursue these aims in quite different ways. Industry giant Merck, for example, spreads its search efforts globally, working with research institutes in France, Canada, China, Japan, Costa Rica, and the United States, while pursuing research partnerships with but a few

biotechs such as Affymetrix and Transcell to access new technologies. In addition, Merck has innumerable licensing agreements, as well as arrangements to do manufacturing, marketing, and sales for smaller companies. Eli Lilly, another big pharmaceutical player, but about two-thirds the size of Merck, has both more focused and more extensive collaborations. Pursuing a strategy of "discovery without walls," Lilly has several dozen research alliances with a wide variety of U.S. biotech firms, ranging from new startups to more established companies. In addition to these extensive external discovery efforts, Lilly also has licensing and joint sales and distribution agreements with biotechs, but the clear emphasis has been on the research side. The Swiss firm Hoffman LaRoche, one of the largest firms in the industry, has an even more focused approach, owning 66% of the stock in the U.S. biotech firm Genentech, in addition to multiple research, development, and marketing collaborations with Genentech. Roche counts Amgen, Affymetrix, and several other biotechs as partners also, but it utilizes Genentech as its primary talent scout to stay abreast of the field.

At a more micro level, however, these collaborative profiles have their origins in myriad small decisions, stemming from different purposes and initiated by different parties. At one of the larger U.S. pharmaceutical firms, I was involved in a multi-year internal executive development program. During this time, I had regular contact with senior managers on the science side, in the finance and strategy groups, and those in charge of the different therapeutic product lines. I used our conversations to informally trace the origins of the more than twenty R&D partnerships the firm has with various small biotechs. In following these different "stories," it became apparent that collaborations emerged from very different routes. Some were brought forward by business development staff who had "found" young biotechs in financial trouble and in need of cash. Thus, promising technology could be "had" inexpensively. In other circumstances, however, breakthrough technologies triggered great interest throughout the pharmaceutical industry, and all the major players were part of the gold rush, bidding for the new discovery. In still other cases, long-standing personal ties among scientists, sometimes forged decades earlier at universities, led to formal collaborations. Other partnerships were driven by a pressing need to fill out a product portfolio or to replenish the product pipeline in a particular therapeutic category. And still other connections literally fell into their laps, as biotech firms approached the company with proposals that proved viable.

I use these examples of very different starting points not to suggest that the process of deciding which parties to collaborate with is random or haphazard, but to illustrate that there are, especially in a larger company, multiple inputs and opportunities and many decision makers involved. Except in the smallest companies, the same people rarely review all the relevant information and make decisions about whom to ally with and under what terms and for what period of time. Nor should such decisions necessarily be made by the same people or units. But what is necessary is the ability to negotiate two hurdles, the first leaping from information to knowledge, and the second jumping

from individual-level learning and expertise to organizational-level learning and routines. In any technology-intensive field, information is abundant and accumulates rapidly. Long ago, Herbert Simon alerted us to the fact that, increasingly, attention is the scarcest commodity in organizations. As firms embark on different combinations of formal and informal collaborations and divergent mixes of external sourcing and internal production, the parties who are most closely involved with outsiders develop skills at relational contracting: How much of an agreement needs to be specified in a contract? How much should rest on a handshake or good faith? What role should the "entangling strings" of friendship or reputation play? What kinds of milestones or interventions are needed to insure a project stays on course?[15] In short, knowledge of how to collaborate means that information is filtered by a specific context and an ongoing relationship, by experience and reflection, and by interpretation. When multiple participants are involved, and their availability varies, making knowledgeable decisions is a challenge.

But even more daunting is moving from individual learning (which is embodied in experienced personnel) to organization-level learning (in which the skills of relational contracting become embedded in organizational routines and procedures) without rendering those competencies lifeless and inert. As an illustration, Richard Di Marchi, Vice President for Endocrine Research at Eli Lilly and Company, remarks that one of the bigger challenges his company faces in managing research partnerships with small firms is in not treating them as "one-offs," that is, independent relationships pursued separately. On the other hand, it is ineffective to force all decisions about collaboration to go forward only after the decision has been vetted by a key committee, composed of staff from different business functions. Such a move can result in a needless delay, which is fatal in a fast-moving field, and can also dampen initiative. Another side-effect of formalizing the approval process is to force external relationships underground, into subterranean linkages, as savvy managers opt to pursue relationships without risking going through the rigamarole of formal approval. But covert efforts may run the risk that key intellectual property or process issues are not aired at the outset. The challenge, then, is to develop routines for cooperation that are widely shared, that apply across decisions, and allow for lessons to be transferred from project to project. In the biotechnology and pharmaceutical fields, firms vary enormously in their capacity to learn across projects.

Learning How and What to Learn

My claim that learning from collaboration is both a function of access to knowledge and possession of capabilities for utilizing and building on such knowledge is not a claim that individuals and organizations are exceedingly calculating or far-sighted. In making the argument that knowledge facilitates the acquisition of more knowledge, I am building on research that stresses that skills are embedded in the exercise of routines. The development of these routines is a

key feature in explaining the variability of organizations' capacity for learning. Only by building these skills can knowledge be transferred from one project to another, from one unit to another, in a manner that allows insights gained from one set of experiences to shape subsequent activities.

Most firms in biotech and pharmaceuticals have key individuals who function as network managers, "marriage counselors," and honest brokers. These individuals provide the glue that sustains relationships between parties who have ample opportunities to question one another's intentions or efforts. The participants in a collaboration often learn at very different speeds, prompting one side to wonder if it is benefitting equally. Moreover, the wealthier party is sometimes regarded as a "sugar daddy," present only to write checks. So there are numerous situations where monitoring and interventions are needed to maintain balance in a collaboration. A critical task for the participants enmeshed in a web of many such relationships is to take lessons learned on one project and make them systemic, that is, portable across multiple relationships.

Finding solutions to the problem of learning how to learn is critical for both small and large firms. Biotech companies have created organizational capabilities well out of proportion to their relatively small size by building on relationships with external parties to gain access to resources, knowledge, and skills to support every organizational function from R&D to distribution. And given the huge sums that pharmaceuticals are pouring into biotech, these large firms have had to find methods to harmonize and coordinate their far-flung partnerships. The steps involved range widely, and it is probably too early to pronounce some efforts most efficacious. Clearly not all firms maneuver with equal ease, have comparable access, or utilize high-quality partners with similar results. But some methods do hold promise for facilitating learning.

An enormous amount of information and knowledge resides in the minds and electronic mail of key people, but this material is rarely organized in a fashion that allows for its transmission to others. Some firms build repositories, where contracts, milestone agreements, working papers, publications, press releases, and overheads are stored. These data banks are primarily useful for novices and new hires. A few firms have set up discussion databases in which archival material and reports are enlivened with notes and chat-room-like interactions about lessons learned. These more active sources, where key participants record their experiences as well as respond to others, are potentially quite valuable. Nevertheless they have, according to some informants, a somewhat sterile feel to them, like critiquing others' critiques of a performance, rather than engaging the performance itself. And, to many people, there simply is not sufficient time to join in these discussions. They are too busy with the press of daily activities.

Informal seminars on lessons learned from a partnership, particularly when staff from multiple functions are involved, are a good way to transmit experience across projects. Only limited effort needs to be made to organize such presentations, so they have the advantage of freshness and a hands-on feel.

Nevertheless, these seminars, unless performed on a more or less regular basis, are much more valuable in a smaller company than a larger one because the information diffuses more extensively. I have not personally encountered any case where participants from both sides of a collaboration made a joint presentation, although almost every time I suggest such an approach, I am met with a comment, "That would be interesting!" Talking about failures, shortcomings, and rough spots in a relationship would be equally as valuable as discussions of successes and lessons learned. But I have rarely seen presentations where such difficulties are openly discussed. To be sure, these conversations are often pursued, heatedly, but off-stage, again the closed nature of the discussion inhibits the transfer of information. Moreover, problematic points are often dismissed as idiosyncratic to a particular party and not felt to be generalizable. While there is, of course, truth to such claims, a large part of building a reputation as a preferred partner is learning how to broker unexpected disputes.

Many biotech and pharmaceutical firms turn to multi-functional teams to supervise collaborative activities, building on the popular idea of the heavyweight teams used in product development efforts. The more thoughtful teams opt to disseminate their discussions either through electronic posting of minutes of their meetings or by having different participants act as scribes to send out short summaries of meetings.

In all these activities, there is a persistent tension between those activities done informally and on an ad hoc basis and those efforts that are more formalized and structured. Clearly, there are tradeoffs with both approaches. The insight appreciated by only a minority of the firms that we have had contact with is that developing routines for the transmission of information and experience does not necessarily entail formalization. Information can be conveyed routinely through informal means. While formal repositories and powerful task forces can be useful, they are too often not a forum in which outside input is allowed. Building routines for regular contact without formalization allows for the possibility that participants not only contribute ideas, they will take lessons learned and spread them in unexpected and unobtrusive ways.

Conclusion

In innovation-driven fields, firms are engaged in learning races. These contests proceed on parallel tracks, one involving learning *from* collaborations, the other concerns learning *how* to collaborate. Both contests require the development of skills to facilitate the transfer of information and knowledge and their subsequent deployment in other situations. In some respects, the task of learning from outside parties is more difficult. But perhaps because of the importance of the task and/or its considerable expense, organizations in the biotechnology and pharmaceutical fields are rapidly developing the capability to collaborate with a diverse array of partners to speed the timely development of new medicines. Much less refined is the more mundane but difficult and vital task of

transferring information and knowledge obtained from external parties throughout the organization. This is done in order that subsequent actions are informed by, and strategic thinking based on, these experiences. A variety of efforts at learning are underway, ranging from electronic discussions to data depositories to seminars to regular meetings of heavyweight teams. All these activities reflect efforts to see that information becomes more widely diffused, and that with reflection and interpretation, becomes "thickened" into knowledge. But developing routines for knowledge dissemination is always a double-edged sword: informal mechanisms may preclude wide dissemination, while formal procedures can inhibit learning. The challenge is to develop regular venues for the informal transmission of information, such that the process itself becomes tied to knowledge seeking and creation.

Notes

1. See data presented in National Science Board, *Science and Technology Indicators—1996* (Washington, D.C.: U.S. Government Printing Office, 1996).
2. A good discussion is found in H. Chesbrough and D.J. Teece, "When Is Virtual Virtuous: Organizing for Innovation," *Harvard Business Review*, 74/1 (January/February 1996): 65-73.
3. See O. Williamson, "Comparative Economic Organization," *Administrative Science Quarterly*, 36 (1996): 269-296; O. Hart, *Firms, Contracts, and Financial Structure* (New York, NY: Oxford University Press, 1995).
4. Representative examples include Paul Joskow, "Contract Duration and Relation-Specific Investments," *American Economic Review*, 77 (1987): 168-195; Gary Pisano and P.Y. Mang, "Collaborative Product Development and the Market for Know-How," *Research on Technological Innovation, Management, and Policy*, 5 (1993): 109-136; Phillipe Aghion and Jean Tirole, "On the Management of Innovation," *Quarterly Journal of Economics*, 109 (1994): 361-379.
5. See, for example, Mark Granovetter, "Economic Action and Social Structure: The Problem of Embeddedness," *American Journal of Sociology*, 91 (1985): 481-510; Charles Sabel, "Learning by Monitoring," in N. Smelser and R. Swedberg, eds., *Handbook of Economic Sociology* (Princeton, NJ: Princeton University Press, 1994), pp. 137-165; Brian Uzzi, "The Sources and Consequences of Embeddedness for the Economic Performance of Organizations," *American Sociological Review*, 61 (1996): 624-648.
6. Walter W. Powell, Kenneth Koput, and Laurel Smith-Doerr, "Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology," *Administrative Science Quarterly*, 41 (1996): 116-145; Peter Grindley and David Teece, "Managing Intellectual Capital: Licensing and Cross-Licensing in Semiconductors and Electronics," *California Management Review*, 38/2 (Winter 1997): 8-41.
7. Josh Lerner and Robert P. Merges, "The Control of Strategic Alliances: An Empirical Analysis of Biotechnology Collaborations," unpublished manuscript, Harvard Business School.
8. Powell et al., op. cit.
9. On the diffusion of matrix management, see L.R. Burns and D. R. Wholey, "Adoption and Abandonment of Matrix Management Programs," *Academy of Management Journal*, 36 (1993): 106-138; on the spread of the "poison pill," see G. Davis, "Agents Without Principles?" *Administrative Science Quarterly*, 36 (1991): 583-613; on the multidivisional form, see D. Palmer, P.D. Jennings, and X. Zhan, "Late

Adoption of the Multidivisional Form by Large U.S. Corporations," *Administrative Science Quarterly*, 38 (1993): 100-131; on the diffusion of total quality management, see J.D. Westphal, R. Gulati, and S. Shortell, "Customization or Conformity," *Administrative Science Quarterly*, 42 (1997): 366-394.

10. Walter W. Powell and Laurel Smith-Doerr, "Networks and Economic Life," in N. Smelser and R. Swedberg, eds., *Handbook of Economic Sociology* (Princeton, NJ: Princeton University Press, 1994), pp. 368-402; Richard S. Rosenbloom and Williams J. Spencer, "The Transformation of Industrial Research," *Issues in Science and Technology*, 12/3 (1996): 68-74.
11. For introductions to the political sociology literature, see Gerald Maxwell and Pamela Oliver, *The Critical Mass in Collective Action* (Cambridge: Cambridge University Press, 1993); Sidney Tarrow, *Power in Movement: Social Movements, Collective Action, and Politics* (Cambridge: Cambridge University Press, 1994).
12. This argument draws freely on Cohen and Levinthal's ideas about absorptive capacity, Nelson and Winter's work on developing routines for learning, and Brown and Duguid's ideas on situated learning. See Wesley Cohen and Daniel Levinthal, "Absorptive Capacity: A New Perspective on Learning and Innovation," *Administrative Science Quarterly*, 35 (1990): 128-152; Richard Nelson and Sidney Winter, *An Evolutionary Theory of Economic Change* (Cambridge, MA: Harvard University Press, 1982); John Seeley Brown and Paul Duguid, "Organizational Learning and Communities-of-Practice," *Organization Science*, 2 (1991): 40-57.
13. Lawrence M. Fisher, "Biogen's Triumph against the Odds," *Strategy and Business*, 8 (3rd Quarter 1997): 55-63.
14. See Erick Schonfield, "Merck vs. the Biotech Industry: Which One Is More Potent?" *Fortune*, March 31, 1997, pp. 161-162.
15. See Ian Macneil, "Relational Contracting: What We Do and Do Not Know," *Wisconsin Law Review*, 3 (1985): 483-526.