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*Edited by Jacob H. Rooksby*

# Research Handbook on Intellectual Property and Technology Transfer

*Edited by*

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*To Foster—A curious mind is the most beautiful thing*

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The above recognitions notwithstanding, any errors or oversights in the framing or editorial work associated with this book are completely my own.

Jacob H. Rooksby

# Abbreviations

| | |
|---|---|
| AAU | Association of American Universities |
| APLU | Association of Public and Land-grant Universities |
| AUTM | Association of University Technology Managers |
| CAFC | United States Court of Appeals for the Federal Circuit |
| IP | Intellectual property |
| OECD | Organisation for Economic Cooperation and Development |
| TTO(s) | Technology transfer office(s) |
| USPTO | United States Patent and Trademark Office |

# 10. Tacit knowledge and university-industry technology transfer

*Peter Lee*

*We can know more than we can tell.*[1]

## I. INTRODUCTION

Traditional conceptions of university-industry technology transfer typically focus on patenting and licensing of academic inventions. However, effective technology transfer often requires significant knowledge exchange between academic and commercial entities in parallel to patent licensing. Although patents on university technologies nominally disclose those inventions, a significant amount of knowledge related to practicing and commercializing them remains tacit or uncodified, residing in the mind of the faculty inventor. This Chapter explores the nature of tacit knowledge and mechanisms for transferring it. It reveals that human and institutional connections play a critical role in transferring tacit knowledge between universities and commercial firms and thus facilitating technology transfer.

In exploring these dynamics, this Chapter does not seek to diminish the importance of formal patenting and licensing as well as the legal and institutional framework that shapes it. Certainly, the governing federal statutory regime has been highly impactful. Particularly noteworthy is the 1980 Bayh-Dole Act, which allows and encourages recipients of federal funding (including universities) to take title to patents arising from publicly funded research.[2] While university patenting was already on the rise at the time of its enactment,[3] the Act greatly accelerated such activity.[4] This statutory innovation dovetailed with other legal changes, such as expansive Supreme Court rulings on patentable subject matter[5] and the creation of the Court of Appeals for the Federal Circuit in 1982,[6] to create an environment that accelerated university patenting.[7] These legal changes helped spur institutional changes, such as the establishment of

1 Michael Polanyi, *The Tacit Dimension* 4 (1967) [hereinafter Polanyi, *The Tacit Dimension*].

2 35 U.S.C. §§ 200–211 (Supp. 2009). The Bayh-Dole Act and its impact are emblematic of the "triple helix" model of greater interaction among government, academia, and business. *See* Henry Etzkowitz & Riccardo Viale, *Polyvalent Knowledge and the Entrepreneurial University: A Third Academic Revolution?*, 36 Crit. Soc. 595, 600 (2010).

3 David C. Mowery et al., *Ivory Tower and Industrial Innovation: University-Industry Technology Transfer Before and After the Bayh-Dole Act in the United States* 104 (2004).

4 Peter Lee, *Patents and the University*, 63 Duke L.J. 1, 34 fig.1 (2013) [hereinafter Lee, *Patents and the University*].

5 *See, e.g.*, *Diamond v. Chakrabarty*, 447 U.S. 303, 310 (1980); *Diamond v. Diehr*, 450 U.S. 175, 192 (1981).

6 The Federal Courts Improvement Act, 96 Stat. 25 (1982).

7 Additionally, scientific advances such as the discovery of recombinant DNA technology also accelerated university patenting. *See* Lee, *Patents and the University*, *supra* note 4, at 32–3.

hundreds of technology transfer offices ("TTOs") on university campuses to manage academic patenting and licensing.[8] These TTOs collect invention disclosures from university scientists, determine whether to pursue patenting, coordinate prosecution, find licensees, and negotiate licenses with commercial partners. In the traditional view, technology transfer is effectuated when a TTO licenses a university patent to a commercial licensee.

This Chapter, however, reveals that patent licensing alone frequently does not provide the requisite knowledge necessary to transfer and develop university inventions. While patents must disclose an invention, much invention-related knowledge remains tacit and difficult to access by a commercial licensee. Part II of this Chapter addresses the nature of tacit knowledge, which ranges from purely tacit knowledge incapable of codification to latent knowledge that is codifiable but uncodified. It further observes that tacit knowledge is highly valuable to commercial licensees both for practicing a basic invention and for commercializing it. It also explores the difficulty of transferring tacit knowledge, which usually requires direct interpersonal interaction between inventor and transferee. Part III draws on these observations to explore a variety of relational and institutional mechanisms for transferring patent-related tacit knowledge. Among other functions, networks, consulting engagements and corporate positions, sponsored research, proof of concept centers and incubators, and university spinoffs all facilitate the transfer of tacit knowledge from academic to commercial entities. Part IV explores several implications of the central role of tacit knowledge in university-industry technology transfer, including the geographically constrained nature of technology transfer and normative concerns over greater intermeshing of academic and commercial entities.

## II. TACIT KNOWLEDGE

The act of invention draws upon and generates multiple kinds of knowledge, some of which are more easily communicated than others. Even for university inventions that have been disclosed in a patent, tacit knowledge on the part of a faculty inventor can be immensely valuable for a commercial licensee seeking to adopt and commercialize a technology. This Part explores the nature of tacit knowledge, which varies in degree for different types of technologies. It further examines the commercial value of such knowledge, which is helpful for both practicing a basic invention and for commercially developing it. Finally, it discusses the costly, human-centric processes necessary to transfer tacit knowledge, thus rendering such transfer one of the central challenges of commercializing university inventions.

### A. Dimensions

Numerous commentators have explored the importance of tacit knowledge in innovation and technology transfer.[9] In his seminal writings,[10] scientist and philosopher Michael Polanyi

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8 Richard R. Nelson, *Observations on the Post-Bayh-Dole Rise of Patenting at American Universities*, 26 J. Tech. Transfer 13, 13 (2001).

9 *See* Jacqueline Senker, *Tacit Knowledge and Models of Innovation*, 4 Indus. & Corp. Change 425, 425 (1995) (collecting sources).

10 *See generally* Michael Polanyi, *Science, Faith and Society* (1964); Michael Polanyi, *Personal Knowledge: Towards a Post-critical Philosophy* (1958) [hereinafter Polanyi, *Personal Knowledge*];

famously observed: "We can know more than we can tell."[11] Tacit knowledge is that which is personal to an individual and not easily reduced to codification,[12] such as the ability to recognize faces, ride a bicycle or swim.[13] As Dan Burk observes, "[s]ome types of knowledge may be inherently uncodifiable because some cognitive capacities resist explicit articulation."[14] Such knowledge is experiential and comprises "rules of thumb, heuristics, and other 'tricks of the trade'."[15] For instance, while a champion golfer can verbally describe how to hit a golf ball, much of the knowledge for actually performing this motion is tacit, residing in subconscious understanding informed by years of practice, muscle memory and athletic intuition.[16] Moving beyond the sporting world, when an inventor creates a new technology, she draws upon and produces a significant amount of tacit knowledge.[17] Such "non-codified, disembodied know how" arises from the internalization of learned behaviors and procedures[18] and is difficult to communicate.

For example, tacit knowledge is highly relevant to biotechnology,[19] an area of significant university innovation.[20] Modern biotechnology involves the use of recombinant DNA technology and monoclonal antibodies to produce biologic compounds based on living material.[21] According to the Office of Technology Assessment, "Because of their complex and unknown

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Polanyi, *The Tacit Dimension*, *supra* note 1*; see also* Richard R. Nelson & Sidney G. Winter, *An Evolutionary Theory of Economic Change* 76–82 (1982); Robin Cowan et al., *The Explicit Economics of Knowledge Codification and Tacitness*, 9 Indus. & Corp. Change 211, 211 (2000).

[11] Polanyi, *The Tacit Dimension*, *supra* note 1, at 4; *see also* Partha Dasgupta & Paul A. David, *Toward a New Economics of Science*, 23 Res. Pol'y 487, 493 (1994).

[12] Lynne G. Zucker et al., *Commercializing Knowledge: University Science, Knowledge Capture, and Firm Performance in Biotechnology*, 48 Mgmt. Sci. 138, 140 (2002) [hereinafter Zucker et al., *Commercializing Knowledge*].

[13] Senker, *supra* note 9, at 426.

[14] Dan L. Burk, *The Role of Patent Law in Knowledge Codification*, 23 Berkeley Tech. L.J. 1009, 1014 (2008).

[15] Ashish Arora, *Contracting for Tacit Knowledge*: *The Provision of Technical Services in Technology Licensing Contracts*, 50 J. Dev. Econ. 233, 234 (1996) [hereinafter Arora, *Contracting for Tacit Knowledge*]; *see also* Érica Gorga & Michael Halberstam, *Knowledge Inputs, Legal Institutions and Firm Structure: Towards a Knowledge-Based Theory of the Firm*, 101 Nw. U. L. Rev. 1123, 1144 (2007).

[16] Burk, *supra* note 14, at 1014.

[17] Polanyi, *Personal Knowledge*, *supra* note 10, at 52; Joanne E. Oxley, *Appropriability Hazards and Governance in Strategic Alliances: A Transaction Cost Approach*, 13 J. L. Econ. & Org. 387, 393 (1997); *see also* Gary P. Pisano, *Can Science Be a Business? Lessons from Biotech*, Harv. Bus. Rev., Oct. 2006, at 10 [hereinafter Pisano, *Can Science Be a Business?*].

[18] Jeremy Howells, *Tacit Knowledge, Innovation and Technology Transfer*, 8 Tech. Analysis & Strategic Mgmt. 91, 92 (1996). Economics and management scholarship typically uses the term "tacit knowledge," while the applied science and research literature typically refers to "know-how." Margaret Chon, *Sticky Knowledge and Copyright*, 2011 Wis. L. Rev. 177, 187. This Chapter generally uses the term "tacit knowledge."

[19] Senker, *supra* note 9, at 430.

[20] *See generally* Zucker et al., *Commercializing Knowledge*, *supra* note 12; Gary P. Pisano et al., "Joint Ventures and Collaboration in the Biotechnology Industry" in *International Collaborative Ventures in U.S. Manufacturing* 183, 187 (David C. Mowery ed., 1988) ("Universities and non-profit research organizations have shaped the scientific foundations for commercial biotechnological development.").

[21] *See* Pisano et al., *supra* note 20, at 184 (offering a concise overview of biotechnology, including modern techniques based on recombinant DNA technology and monoclonal antibodies).

nature, many biological inventions, especially organisms, cannot be sufficiently described in writing to allow their predictable reproducibility on the basis of that description alone."[22] Thus, even if a university scientist describes a biotechnological invention in an academic journal or a patent, much knowledge related to that invention remains tacit.[23] The centrality of tacit knowledge to comprehending an invention, moreover, complicates efforts to transfer that invention to private parties for further development and commercialization.

At this point, it is useful to address how patented inventions, including university technologies, may not disclose valuable tacit knowledge. After all, patent law requires that applicants disclose their inventions "in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same."[24] Furthermore, patent law requires that applicants "shall set forth the best mode contemplated by the inventor of carrying out his invention."[25] Indeed, the essential quid pro quo of the patent system comprises an exchange of exclusive rights for technical disclosure.[26] While the disclosure requirements of patentability suggest that patented inventions should have little remaining tacit content,[27] that is often not the case;[28] the enablement and written description requirements still permit many knowledge gaps.[29] Patent law does not require applicants to provide detailed production specifications[30] or to disclose their inventions thoroughly enough to eliminate the need for technical artisans to engage in some experimentation to practice them.[31] Patents applicants have strong incentives to disclose as little as possible,[32] and they often employ unwieldy jargon and formalism[33] that obfuscates rather than illuminates. Furthermore, patent disclosure occurs early in the application process and is generally fixed, thus discouraging the applicant from disclosing newly discovered information during prosecution.[34] Additionally, the "best mode" requirement—which mandates disclosure of specific techniques and instrumentalities known to the applicant as the best way of practicing an invention—is largely a dead letter after statutory reforms in 2011.[35] According to one

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22 Office of Technology Assessment, *Commercial Biotechnology—An International Analysis* 368 (1984).

23 Peter Lee, *Innovation and the Firm: A New Synthesis*, 70 Stan. L. Rev. 1431, 1446 (2017) [hereinafter Lee, *Innovation and the Firm*].

24 35 U.S.C. § 112(a) (2012).

25 *Id*.

26 *Kewanee Oil Co. v. Bicron Corp.*, 416 U.S. 470, 484 (1974).

27 Burk, *supra* note 14, at 1012.

28 Douglas Lichtman, *How the Law Responds to Self-Help*, 1 J.L. Econ. & Pol'y 215, 255 (2005) ("The information available on the face of a patent document is rarely revealing.").

29 *See*, *e.g.*, Timothy R. Holbrook, *Possession in Patent Law*, 59 S.M.U. L. Rev. 123, 132–46 (2006); James Bessen, *Patents and the Diffusion of Technical Information*, 86 Econ. Letters 121, 122 (2005); Jeanne C. Fromer, *Dynamic Patent Disclosure*, 69 Vand. L. Rev. 1715, 1718 n.13 (2016) (collecting sources).

30 *In re Gay*, 309 F.2d 769, 774 (C.C.P.A. 1962).

31 *See In re Wands*, 858 F.2d 731 (Fed. Cir. 1988) (exploring the "undue experimentation" standard for assessing compliance with the enablement requirement).

32 *See Brenner v. Manson*, 383 U.S. 519, 534 (1966) (critiquing patent drafting techniques that disclose little while claiming much).

33 Sean B. Seymore, *The Teaching Function of Patents*, 85 Notre Dame L. Rev. 621, 626 (2010).

34 Fromer, *supra* note 29, at 1719–20.

35 *See* 35 U.S.C. § 282(b)(3)(A) (2012) (establishing that the failure to disclose a best mode is not a permissible ground for invalidating a patent or rendering it unenforceable).

observer, "even if a university invention is highly codified in terms of a pending patent, some knowledge that is relevant for commercialization is still tacit and has to be made available by human interactions."[36]

In exploring the nature of tacit knowledge, several distinctions are helpful. First, tacitness is not a binary designation but a question of the degree.[37] At one end of the spectrum lies purely tacit knowledge that is not capable of expression in explicit form.[38] Toward the other end of the spectrum is "latent" knowledge that is technically codifiable but uncodified.[39] For example, a university scientist who creates a new recombinant DNA may not reveal certain details of the best way for producing it, even though those details are capable of codification. Latent knowledge may remain uncodified for a variety of reasons, including the high cost of codification,[40] a lack of incentive to codify, or an affirmative desire *not* to codify to advance self-interest.[41] For instance, while a scientist may report research findings in an academic article, she may not feel it is worthwhile to disclose a novel measuring instrument that she developed in the course of her research; this research "byproduct" may be highly valuable yet remain in tacit form.[42] Toward the far end of the spectrum lies explicitly codified knowledge, perhaps as disclosed in a patent or article. Even explicit knowledge, however, requires tacit knowledge to be understood and acted upon.[43] Second, some commentators distinguish tacit knowledge, which rests upon understanding, from skills, which encompass the ability to make something happen, such as through manual dexterity or sensory ability.[44] Other commentators, however, group tacit knowledge and skills together.[45] Third, utilizing confusingly similar terminology, commentators also observe that different types of tacit knowledge manifest in different types of entities. "Skills," such as those necessary to perform a difficult experimental

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[36] Fritjof Karnani, *The University's Unknown Knowledge: Tacit Knowledge, Technology Transfer and University Spin-Offs Findings from an Empirical Study Based on the Theory of Knowledge*, 38 J. Tech. Transfer 235, 238 (2012).

[37] Michael D. Santoro & Shanthi Gopalakrishnan, *Assimilating External Knowledge: A Look at University-Industry Alliances*, Proc. of PICMET 15 227, 229 (2015) (describing a continuum between tacit and explicit knowledge).

[38] *Cf.* Nelson & Winter, *supra* note 10, at 73 (characterizing the knowledge underlying serving a tennis ball as largely tacit).

[39] *See* Ajay Agrawal, *Engaging the Inventor: Exploring Licensing Strategies for University Inventions and the Role of Latent Knowledge*, 27 Strategic Mgmt. J. 63 (2006) [hereinafter Agrawal, *Engaging the Inventor*].

[40] James E. Bessen, *From Knowledge to Ideas: The Two Faces of Innovation* 3 (Mar. 1, 2011) (unpublished manuscript), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1698802 (last visited Apr. 24, 2019) [hereinafter Bessen, *From Knowledge to Ideas*].

[41] *See* Chon, *supra* note 18, at 191; *cf.* H.M. Collins, *The TEA Set: Tacit Knowledge and Scientific Networks*, 4 Sci. Stud. 165, 180 (1974) ("Let's say I've always told the truth, nothing but the truth, but not the whole truth.") (quoting a scientist involved in transferring the TEA laser to another laboratory).

[42] *Cf.* Karnani, *supra* note 36, at 236.

[43] Collins, *supra* note 41, at 167 ("All types of knowledge, however pure, consist, in part, of tacit rules which may be impossible to formulate in principle."); Miriam Knockaert et al., *The Relationship Between Knowledge Transfer, Top Management Team Composition, and Performance: The Case of Science-Based Entrepreneurial Firms*, 35 Entrepreneurship Theory & Prac. 777, 780 (2010).

[44] Senker, *supra* note 9, at 427.

[45] Ikujiro Nonaka, *A Dynamic Theory of Organizational Knowledge Creation*, 5 Org. Sci. 14, 16 (1992).

protocol, reside in individuals, while "routines," such as laboratory workflow processes, reside in organizations.[46]

Continuing the theme of distinctions, the tacit dimension of any given technology is highly context specific.[47] Some inventions are easily comprehensible even absent any formal codification. Many patented commercial products are "self-disclosing" in that they intrinsically reveal how they are made and used.[48] Similarly, even early-stage university inventions may self-disclose their mode of manufacture and function. For example, an early-stage mechanical device developed in a university engineering department may be easily comprehensible even absent explicit codification. For such straightforward inventions, the tacit dimension is relatively low, thus easing technology transfer.[49] For other inventions, codification through patenting, publishing or other means is sufficient to adequately disclose and transfer an invention. At the far end of the spectrum, however, are inventions in more "unpredictable" arts like chemistry and experimental sciences[50] that may possess a significant tacit dimension. These technologies do not self-disclose how they operate, and codification cannot adequately describe how to make and use them. As we will see, early-stage university inventions encompassing cutting-edge technology tend to have a high tacit dimension.[51]

On a related note, tacitness is also a function of time. New information tends to emerge in tacit form but become codified over time[52] as "recipe knowledge."[53] In particular, knowledge pertaining to a pioneering scientific discovery may initially arise in tacit form, as only the discoverer herself can understand and exploit it. Over time, however, knowledge tends to lose its tacit dimension as pioneering discoveries become widely shared background knowledge. For instance, early biotechnology innovations maintained a significant tacit dimension for the first ten or fifteen years after discovery, after which they became more readily accessible by the broader scientific community.[54]

## B. Commercial Value

The tacit knowledge retained by a faculty inventor, even when the inventor has disclosed the invention in a patent, is highly valuable. "Utilizing technology requires a great deal

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46 *See* Nelson & Winter, *supra* note 10, at 14, 72–73.

47 *See*, *e.g.*, Senker, *supra* note 9, at 439 tbl.3 (differentiating between different sources of knowledge in biotechnology, ceramics and parallel computing).

48 Katherine J. Strandburg, *What Does the Public Get? Experimental Use and the Patent Bargain*, Wis. L. Rev. 81, 83 (2004) (defining self-disclosing inventions as those "that are easily copied from their commercial embodiments"); Frank H. Easterbrook, *Intellectual Property Is Still Property*, 13 Harv. J.L. & Pub. Pol'y 108, 109 (1990) ("The product itself, not the patent papers, usually discloses things.").

49 Raymond W. Smilor & David V. Gibson, *Technology Transfer in Multi-Organizational Environments: The Case of R&D Consortia*, 38 IEEE Transactions on Engineering Mgmt. 3 (1991).

50 *See* Sean B. Seymore, *Heightened Enablement in the Unpredictable Arts*, 56 UCLA L. Rev. 127, 137–9 (2008).

51 *See infra* notes 62–8 and accompanying text.

52 Zucker et al., *Commercializing Knowledge*, *supra* note 12, at 140.

53 *Id.* at 141; *see also* Senker, *supra* note 9, at 431.

54 *See* Lynne G. Zucker et al., *Intellectual Human Capital and the Birth of U.S. Biotechnology Enterprises*, 88 Am. Econ. Rev. 290, 291 (1998) [hereinafter Zucker et al., *Intellectual Human Capital*].

of know-how,"[55] and tacit knowledge is often necessary to exploit codified knowledge.[56] Accordingly, tacit knowledge is critical for effectively transferring many patented inventions.[57] Patent licensees frequently recognize that "the aggregate value of all the 'minor' improvements, tweaks, and accumulated operational wisdom [related to a patent] often exceeds the value of the basic invention itself."[58] Not surprisingly, companies licensing patents often seek to license invention-related tacit knowledge as well.[59] Indeed, "acquisition of tacit knowledge to support innovation is a purposive activity of much industrial development."[60] Within science-based fields typical of university-industry technology transfer, tacit knowledge exchange from a discovering scientist is positively correlated with a firm's success in commercializing a technology.[61]

While tacit knowledge is valuable for many kinds of technology transfer, it is particularly critical for transferring academic inventions. As noted, new information tends to arise in tacit form and become codified over time.[62] Relatedly, inventions that are more novel and complex are likely to have a higher tacit dimension.[63] Given the pioneering, early-stage nature of academic inventions, tacit knowledge is particularly valuable for effective university-industry technology transfer.[64] One empirical study revealed that over 75% of university inventions were merely proofs of concept or lab-scale prototypes at the time of licensing.[65] Similarly,

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[55] Ashish Arora, *Licensing Tacit Knowledge: Intellectual Property Rights and the Market for Know-How*, 4 Econ. of Innovation & New Tech. 41, 42 and 54 (2006) [hereinafter Arora, *Licensing Tacit Knowledge*].

[56] Robin Cowan & Dominique Foray, *The Economics of Codification and the Diffusion of Knowledge*, 6 Indus. & Corp. Change 595, 599 (1997).

[57] *See* Agrawal, *Engaging the Inventor*, *supra* note 39, at 65 (emphasizing the value of latent knowledge in technology transfer); Jonathan M. Barnett, *Intellectual Property as a Law of Organization*, 84 S. Cal. L. Rev. 785, 801–2 (2011) (discussing "information opacity" as a barrier to technology transfer); Barry Bozeman, *Technology Transfer and Public Policy: A Review of Theory and Research*, 29 Res. Pol'y 627, 642 (2000) ("[T]he extent of transfer of tacit knowledge often has a major impact on the effectiveness of manufacturing technology transfer."); Howells, *supra* note 18, at 97 ("[T]acit knowledge has been a key barrier in the diffusion of technological innovation.").

[58] Robert P. Merges, *A Transactional View of Property Rights*, 20 Berkeley Tech. L.J. 1477, 1501 (2005).

[59] *See* Arora, *Licensing Tacit Knowledge*, *supra* note 55, at 43.

[60] Senker, *supra* note 9, at 428.

[61] Zucker et al., *Commercializing Knowledge*, *supra* note 12, at 143.

[62] *See supra* note 52 and accompanying text.

[63] Zucker et al., *Commercializing Knowledge*, *supra* note 12, at 140–1.

[64] Ajay Agrawal, *University-to-Industry Knowledge Transfer: Literature Review and Unanswered Questions*, 3 Int'l J. of Mgmt. Rev. 285, 293 (2001) [hereinafter Agrawal, *Knowledge Transfer*]; Kwanghui Lim, *The Many Faces of Absorptive Capacity: Spillovers of Copper Interconnect Technology for Semiconductor Chips*, 18 Indus. & Corp. Change 1249, 1252 (2009); Jerry G. Thursby & Marie C. Thursby, *Are Faculty Critical? Their Role in University-Industry Licensing*, 22 Contemp. Econ. Pol'y 162, 170 (2004); *see also* Fiona Murray, *The Role of Academic Inventors in Entrepreneurial Firms: Sharing the Laboratory Life*, 33 Res. Pol'y 643, 650 (2004); *cf.* Bruce Kogut & Udo Zander, *Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology*, 3 Org. Sci. 383, 389 (1992); Janet Bercovitz & Maryann Feldmann, *Entrepreneurial Universities and Technology Transfer: A Conceptual Framework for Understanding Knowledge-Based Economic Development*, 31 J. Tech. Trans. 175, 181 (2006) ("In general, early stage technologies such as those originating at universities require more extensive research investment to reach commercial viability.").

[65] Richard Jensen & Marie Thursby, *Proofs and Prototypes for Sale: The Licensing of University Inventions*, 91 Am. Econ. Rev. 240, 243 (2001).

only 12% were ready for commercial use, and 8% had known manufacturing feasibility.[66] Other research revealed that only 7% of universities technologies were ready for practical or commercial use at the time of licensing, and 40% were proofs of concept.[67] Given the embryonic nature of many university technologies, the need to transfer tacit knowledge to facilitate commercialization is particularly acute.[68]

While tacit knowledge is useful for practicing a basic invention, it is particularly important for developing a basic invention into a commercial product.[69] As noted, faculty inventors need not disclose detailed manufacturing specifications in order to obtain a patent,[70] and universities often license their inventions at a relatively early stage of development.[71] These patents typically cover basic versions of inventions that operate in a laboratory, which may be very different from commercial embodiments of a technology ready for market. For instance, producing a (patented) biologic compound in a laboratory is significantly different from industrially manufacturing it in mass quantities.[72] A host of factors, including cell culture medium, oxygen levels, and temperature can affect the quality and effectiveness of such processes.[73] While there is already a gap between what a patent discloses and the knowledge needed to fully practice a basic invention, there is an even larger gap between patent disclosure and the knowledge needed to produce a commercial product. The inventor's tacit knowledge, which constitutes action-oriented practical intelligence,[74] is highly valuable to commercial licensees. According to one entrepreneur,

> So much of what we call technology transfer is information transfer, knowledge transfer. It's not something that could immediately be put into a product. It might be something that is a tidbit of knowledge that will help somebody in their development efforts at one of our companies.[75]

These "tidbits" of tacit knowledge are highly valuable for firms licensing university patents, and effective innovation often depends on transferring such know-how from the laboratory to production facilities.[76]

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66 *Id*.

67 Thursby & Thursby, *supra* note 64, at 167.

68 *See* Zucker et al, *Commercializing Knowledge*, *supra* note 12, at 141; Cowan & Foray, *supra* note 56, at 595; *cf*. Bessen, *From Knowledge to Ideas*, *supra* note 40, at 3–4 (noting the importance of personal interactions in transferring early-stage technologies).

69 *See* Agrawal, *Engaging the Inventor*, *supra* note 39, at 68.

70 *See*, *e.g.*, *DSL Dynamic Sciences v. Union Switch & Signal*, 928 F.2d 1122 (Fed. Cir. 1991) (holding that a coupler mount assembly that was not commercial-grade was nonetheless reduced to practice for the purposes of patent law).

71 *See supra* notes 62–8 and accompanying text.

72 *See* Gary P. Pisano, *The Governance of Innovation: Vertical Integration and Collaborative Arrangements in the Biotechnology Industry*, 20 Res. Pol'y 237, 244 (1991) (describing the technical challenges of "develop[ing] a large-scale process which preserves the desirable characteristics of the product produced in the lab") [hereinafter Pisano, *Governance of Innovation*].

73 *Id*.

74 See generally Robert J. Sternberg et al., *Practical Intelligence in Everyday Life* (2000).

75 Donald S. Siegel et al., *Toward a Model of the Effective Transfer of Scientific Knowledge from Academicians to Practitioners: Qualitative Evidence from the Commercialization of University Technologies*, 21 J. Engineering Tech. Mgmt. 115, 130 (2004).

76 Pisano et al., *supra* note 20, at 186.

Extrapolating beyond this point, what commercial licensees may seek is not just the static tacit knowledge of a faculty inventor but also her dynamic problem-solving skills in an area of unique technical expertise, which is also a tacit quality. Faculty patentees may not have considered the challenges of commercialization when obtaining their patents, but they are uniquely suited to working on those challenges given their intimate understanding of the underlying technology.[77] For example, in the field of biotechnology, "[i]n the absence of well-defined and well-understood scale-up recipes, ensuring product integrity requires extensive interaction between the scientists who designed a cell in the laboratory and bioprocessing engineers charged with developing the production process."[78] Tacit knowledge has a "dynamic" quality in that it encompasses the inventor's ability to extrapolate from present understanding to solve problems and extend a technology beyond its basic form.

### C. Challenges of Transfer

The immense value of tacit knowledge to firms commercializing academic technologies raises the question of how faculty inventors can transfer it.[79] By definition, tacit knowledge is "sticky"[80] and very difficult to communicate.[81] Codification allows for relatively easy knowledge transfer,[82] but tacit knowledge resides not in texts but in "people, institutions or routines."[83] Several factors complicate the transfer of tacit knowledge. First, transferring tacit knowledge is a deeply human endeavor that requires direct interpersonal interaction.[84] In a classic account of tacit knowledge, Collins describes how laboratories building a TEA laser relied on personal visits, telephone calls or personnel transfer from a source laboratory that

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77 *Cf*. Lee, *Innovation and the Firm*, *supra* note 23, at 1448–9 (discussing innovative human capital).

78 Pisano, *Governance of Innovation*, *supra* note 72, at 244. Additionally, sometimes the downstream commercializing entity has tacit knowledge related to scaling up industrial manufacturing that the inventor herself lacks. Pisano et al., *supra* note 20, at 191; *id*. at 213 ("[T]acit knowledge from actual production experience often plays a key role in the development and application of process innovations.").

79 *Cf*. Thursby & Thursby, *supra* note 64, at 162.

80 *See* Chon, *supra* note 18, at 177; *see* Cowan & Foray, *supra* note 56, at 598.

81 *See* Gorga & Halberstam, *supra* note 15, at 1142; *cf*. Burk, *supra* note 14, at 1015; Dasgupta & David, *supra* note 11, at 494. Difficulties of transferring tacit knowledge increase with its complexity. *See* Kogut & Zander, *supra* note 64, at 388; Agrawal, *Engaging the Inventor*, *supra* note 39, at 64.

82 *See* Bessen, *From Knowledge to Ideas*, *supra* note 40, at 2.

83 Cowan & Foray, *supra* note 56, at 596.

84 Senker, *supra* note 9, at 445 ("Personal interaction is required with the source of the new scientific or technological knowledge in order to capture fully the tacit dimension."); Arora, *Contracting for Tacit Knowledge*, *supra* note 15, at 235 ("[Tacit knowledge transfer] requires, almost by definition, face-to-face contact."); Howells, *supra* note 18, at 93 ("Above all, there are no clear market mechanisms which facilitate the transfer of tacit knowledge directly or by which it can be adequately measured."); Scott Shane, *Selling University Technology: Patterns from MIT*, 48 Mgmt. Sci. 122, 124 (2002) ("[W]hen information is tacit, it must be transferred through interpersonal contact, and economic actors must develop relationship-specific assets to facilitate that transfer."); Oxley, *supra* note 17, at 393 ("[Tacit knowledge] is extremely difficult to transfer without intimate personal contact, involving teaching, demonstration, and participation."); David B. Audretsch & Paula E. Stephan, *Company-Scientist Locational Links: The Case of Biotechnology*, 86 Am. Econ. Rev. 641, 647 (1996); *see* Collins, *supra* note 41, at 177; Cowan et al., *supra* note 10, at 215 (describing the development of the TEA laser and observing that "none of the research teams which succeeded in building a working laser had done so without the participation of someone from another laboratory where a device of this type already had been put into operation").

had already built one.[85] In the corporate context, tacit knowledge transfer "requires personal interaction, for example through secondment or training."[86] Focusing on university-industry technology transfer, tacit knowledge is best exchanged through direct interaction between academic inventors and firms that license their patents.[87] In biotechnology, the complexity of underlying inventions "and their strong tacit character make direct contact between basic (university) and applied (commercial) researchers necessary for successful technology transfer."[88] In short, technology transfer typically unfolds as a "contact sport."[89] Compared to low-cost dissemination mechanisms such as written disclosure, the need to interact with an inventor imposes significant temporal and spatial constraints on transferring tacit knowledge.

Second, tacit knowledge transfer arises through experience and practice.[90] Simply listening to a faculty inventor describe a technology may not be enough; direct interaction and practical application is necessary to transfer and cultivate such knowledge. In similar fashion, scientists gain tacit knowledge not through lectures and manuals but through apprenticeship.[91] Senker notes that tacit knowledge is "heuristic, subjective and internalized" and "is learned through practical examples, experience, and practice."[92] For this reason, companies operating in industries where know-how is critical "must be expert at both in-house research and cooperative research" with external partners such as academic scientists.[93] Empirical analysis suggests that joint work at the lab bench is an important mode of transferring tacit knowledge.[94] Studies have shown that joint laboratory work by star bioscientists (primarily faculty members) and corporate scientists has a consistently positive effect on the performance of biotech firms.[95]

Third and relatedly, tacit knowledge transfer takes time and repeated interactions.[96] The practical, experiential nature of tacit knowledge acquisition takes significant time, which further raises the cost of transfer. Furthermore, there is a diffusionary element to tacit knowledge transfer wherein more contacts over time are likely to transfer more knowledge. Tacit knowledge exchange is not only informal, but it is also in some ways capricious, "a symptom of the lack of organization of inarticulated knowledge into visible, discrete, and measurable units."[97] Informal conversations and happenstance encounters can be important vehicles of tacit

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85 Collins, *supra* note 41, at 177.

86 Senker, *supra* note 9, at 428.

87 Agrawal, *Engaging the Inventor*, *supra* note 39, at 65; *see* Edwin Mansfield, *Academic Research Underlying Industrial Innovations: Sources, Characteristics, and Financing*, 77 Rev. Econ. & Stat. 55, 64 (1995).

88 Pisano et al., *supra* note 20, at 187.

89 Agrawal, *Engaging the Inventor*, *supra* note 39, at 65 (quoting the Director of the MIT Technology Licensing Office); *see id*. at 78 ("[P]rivate contracts (or at least relationships) between the acquiring firm and the inventor are required in order to perform the necessary knowledge transfer.").

90 Senker, *supra* note 9, at 429.

91 *Id*. at 427.

92 *Id*. at 426.

93 Walter W. Powell et al., *Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology*, 41 Admin. Sci. Q. 116, 117–19 (1996) (citing Eric Von Hippel, *The Sources of Innovation* (1988)).

94 Zucker et al., *Commercializing Knowledge*, *supra* note 12, at 151.

95 Lynne G. Zucker et al., *Geographically Localized Knowledge: Spillovers or Markets?*, 36 Econ. Inq. 65 (1998).

96 *See* Bercovitz & Feldmann, *supra* note 64, at 181 (noting the importance of "close and ongoing interactions" to transfer early-stage technologies); Knockaert et al., *supra* note 43, at 780.

97 Collins, *supra* note 41, at 171.

knowledge transmission. Unlike one-off market transactions, effective technology transfer—which often encompasses tacit knowledge exchange—unfolds in extended relationships.[98]

Empirical studies underscore the importance of direct participation of faculty inventors in successful university-industry technology transfer. A survey of TTOs at US research universities revealed that 71% of licensed inventions required faculty cooperation for successful commercialization.[99] Other research revealed that roughly 40% of all university licenses required faculty involvement.[100] From the perspective of companies commercializing academic discoveries, 70% of entrepreneurs in one survey recognized "informal transfer of know how" as an output of university technology transfer.[101] In sum, personal interactions are critical to transferring tacit knowledge, which is highly valuable for commercially developing university inventions.

## III. MECHANISMS FOR TRANSFERRING TACIT KNOWLEDGE

Given the value and difficulty of transferring tacit knowledge, mechanisms are often necessary to effectuate such transfers in parallel to patent licensing. These mechanisms span informal vehicles such as professional and social networks to more formal arrangements such as consulting and sponsored research agreements. At the most formalized end of the spectrum, institutional integration between academic and commercial entities facilitates tacit knowledge exchange and technology transfer more broadly. While varied in their characteristics, all of these vehicles facilitate the interpersonal, practice-oriented and repeated interactions necessary for transmitting tacit knowledge.[102] While this Part focuses on how faculty inventors, universities and firms exploit knowledge-exchange mechanisms to supplement patent licensing, these mechanisms perform this function outside of formal technology transfer as well.[103]

### A. Networks

At the most informal end of the spectrum, professional and social networks facilitate tacit knowledge transfer and provide introductions leading to more intensive knowledge

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[98] Peter Lee, *Transcending the Tacit Dimension: Patents, Relationships, and Organizational Integration in Technology Transfer*, 100 Calif. L. Rev. 1403, 1539 (2012) [hereinafter Lee, *Transcending*]; Bercovitz & Feldmann, *supra* note 64, at 182 (emphasizing the role of relationships in university-industry technology transfer); *see generally* Eric Von Hippel, *Sources of Innovation* (1988); *cf*. Powell et al., supra note 93, at 119–20 (noting how long-term relationships can approximate the economies of team learning within an integrated firm).

[99] Jensen & Thursby, *supra* note 65, at 243.

[100] Thursby & Thursby, *supra* note 64, at 170; *see also* Mowery et al., *supra* note 3, at 159–66, 169–76 (2004) (describing the importance of faculty inventor involvement in the development of gallium nitride, a wide band gap semiconductor, and the Ames II test).

[101] Siegel et al., *supra* note 75, at 126, 130.

[102] This is not an exhaustive list of transfer mechanisms. For instance, knowledge exchange also occurs through hiring research students and graduates. Bercovitz & Feldmann, *supra* note 64, at 177.

[103] *Cf. id*. at 176–7 ("Universities' relationships with industry are formed through a series of sequential transactions such as sponsored research, licenses, spin-off firms and the hiring of students.").

exchange.[104] According to Barry Bozeman, "much of scientific and technical human capital is embedded in social and professional networks of technological communities."[105] Even before any patenting and licensing, companies utilize networks spanning academic communities to access the background knowledge necessary to exploit new innovations. Networks are particularly valuable when relevant knowledge is widely distributed among different sources, such as in the biotechnology industry.[106] Technical personnel directly transfer tacit knowledge through personal and professional networks.[107] More broadly, participation in such networks enhances the "absorptive capacity"[108] of industrial scientists seeking to appropriate new academic discoveries.[109] Furthermore, networks provide companies access to a different type of uncodified knowledge: information about promising new technologies under development in university laboratories.[110]

While casual encounters within networks may be too fleeting to transfer some tacit knowledge, these relationships can set the stage for more intensive knowledge exchange. As sociologist Walter Powell and his colleagues have observed, "Beneath most formal ties … lies a sea of informal relations."[111] Not surprisingly, academic engagement with industry is more common among well-connected faculty members with significant social capital.[112] Interestingly, however, weak connections that traverse significant sociological distance may be the most important for innovation networks,[113] as they open up new and unexpected sources of information.

Empirical work by Powell and others on the biotechnology industry demonstrates the importance of networks in knowledge exchange between academic and commercial entities. Empirical data from the late 1980s and early 1990s demonstrate the close relationships between academic communities and leading biotech firms like Genentech and Chiron.[114] "[B]iotech firms grow by being connected to benefit-rich networks,"[115] and collaborative

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[104] *See generally* Laurel Smith-Doerr, "Network Analysis" in *International Encyclopedia of Economic Sociology* 472 (Jens Beckert & Milan Zafirovski eds., 2006); *see* Bercovitz & Feldmann, *supra* note 64, at 176 ("[A] growing literature documents the importance of social interaction, local networks, and personal communication in knowledge transmission.").

[105] Barry Bozeman et al., *The Evolving State-of-the-Art in Technology Transfer Research: Revisiting the Contingent Effectiveness Model*, 44 Res. Pol'y 34, 40 (2015).

[106] Powell et al., *supra* note 93, at 119 ("[W]hen knowledge is broadly distributed and brings a competitive advantage, the locus of innovation is found in a network of interorganizational relationships.").

[107] *Cf.* Eric von Hippel, *Cooperation Between Rivals: Informal Know-how Trading*, 16 Res. Pol'y 291, 292 (1987).

[108] Wesley M. Cohen & Daniel A. Levinthal, *Absorptive Capacity: A New Perspective on Learning and Innovation*, 35 Admin. Sci. Q. 128 (1990). Absorptive capacity is a multidimensional phenomenon encompassing learning from external sources, transferring external knowledge, and assimilating such knowledge to develop new products. Santoro & Gopalakrishnan, *supra* note 37, at 227.

[109] Powell et al., *supra* note 93, at 120.

[110] Audretsch & Stephan, *supra* note 84, at 646; *cf.* Powell et al., *supra* note 93, at 187 ("Linkages with a major university or research institute (including teaching hospitals) are viewed by industry as necessary to track and exploit a rapidly expanding technological frontier.").

[111] Powell et al., *supra* note 93, at 120.

[112] Markus Perkmann et al., *Academic Engagement and Commercialisation: A Review of the Literature on University-Industry Relations*, 42 Res. Pol'y 423, 429 (2013).

[113] Collins, *supra* note 41, at 169.

[114] Powell et al., *supra* note 93, at 141.

[115] *Id*. at 139.

networks represent a critical mechanism for sharing knowledge.[116] Academic and industrial scientists form a common technological community in which professors spend sabbaticals at biotech firms, postdocs move between universities and companies, and universities hire leading commercial scientists.[117] The quasi-academic nature of some biotechnology firms, which reward academic publishing, helps attract university researchers.[118] In a nod to the theory of the firm, Powell describes the upstream-downstream linkages between universities and biotech firms as "virtual integration."[119] Among other functions, such networks serve to transmit tacit knowledge about academic discoveries to commercial partners. While much of the empirical work on networks has focused on biotechnology, the importance of networks likely extends to other fields where knowledge sources are dispersed, such as ceramics and software.[120]

### B. Consulting Engagements and Corporate Positions

While networks can directly facilitate tacit knowledge transfer, they also provide introductions that can lead to more intensive knowledge exchange. For instance, private companies frequently hire academic scientists as consultants,[121] which further facilitates tacit knowledge transfer. Consulting relationships involving academic faculty have become quite common,[122] and many of these relationships arise outside of the context of formal patenting and licensing. Indeed, empirical research indicates that companies value "academic engagement"—which spans consulting, collaborative research, contract research, ad hoc advice, and networking—significantly more than licensing university patents.[123]

However, companies also hire faculty inventors as consultants while licensing those inventors' patents from a university.[124] Not surprisingly, formal patenting and licensing of a university invention heightens firms' interest in interacting directly with academic inventors.[125] One study of licenses from the Mechanical Engineering as well as the Electrical Engineering and Computer Science departments at MIT found that involvement of the academic inventor increased the likelihood of commercialization and the amount of royalties generated.[126] Several qualitative case studies of university-industry licensing highlight the importance of

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[116] *See* Walter W. Powell, *Inter-organizational Collaboration in the Biotechnology Industry*, 152 J. Institutional & Theoretical Econ. 197, 208 (1996); Powell et al., *supra* note 93, at 138–9 ("[N]etworks of collaboration provide entry to a field in which the relevant knowledge is widely distributed and not easily produced inside the boundaries of a firm or obtained through market transactions.").

[117] Powell et al., *supra* note 93, at 123.

[118] *Id*.

[119] Powell, *supra* note 116, at 209.

[120] Powell et al., *supra* note 93, at 143.

[121] Bercovitz & Feldmann, *supra* note 64, at 178.

[122] Karen Seashore Louis et al., *Entrepreneurs in Academe: An Exploration of Behaviors Among Life Scientists*, 34 Admin. Sci. Q. 110, 113 (1989); *see also* Martin Kenney, *Biotechnology: The University-Industrial Complex* 91–3 (1986); Mansfield, *supra* note 87, at 64.

[123] Wesley Cohen et al., *Links and Impacts: The Influence of Public Research on Industrial R&D*, 48 Mgmt. Sci. 1 (2002).

[124] *See* Kenney, *supra* note 122, at 104.

[125] Albert N. Link et al., *An Empirical Analysis of the Propensity of Academics to Engage in Informal University Technology Transfer*, 16 Indus. & Corp. Change 641, 642 (2007).

[126] Agrawal, *Engaging the Inventor*, *supra* note 39, at 16.

ongoing interactions between the faculty inventor and the licensee during commercialization.[127] Similarly, empirical research reveals that ineffective or nonexistent involvement by faculty inventors contributed to 18% of commercialization failures for technologies licensed from universities.[128] In the technology transfer context, surveys indicate that consulting is the most frequently utilized mechanism for transferring inventor knowledge to a licensee firm.[129] For their part, faculty members may be motivated by financial incentives, technical curiosity or a desire to help commercialize their inventions to work as consultants with companies licensing their inventions.[130]

The importance of faculty involvement in commercializing academic technologies is evident in the early biotechnology industry.[131] The participation of "star" bioscientists significantly and positively influenced the number of products in development, the number of products released, and employment growth.[132] The centrality of academic scientists to the early biotechnology industry illustrates that "university-firm technology transfer for breakthrough discoveries generally involves detectable joint research between top professors and firms that they own or are compensated by."[133] Beyond serving as consultants for finite engagements, academic inventors also serve as permanent technical advisers and may become directors of companies licensing university patents.[134] In the 1970s Herbert Boyer of UCSF and Stanley Cohen of Stanford invented and patented the basic techniques of recombinant DNA technology. Stanford licensed this technology to numerous biotech companies, including Genentech and Cetus; at the time, Boyer served on Genentech's board of directors and Cohen was a scientific advisor to Cetus.[135] While hiring academic scientists serves several functions—such

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[127] Jeannette Colyvas et al., *How Do University Inventions Get into Practice?*, 48 Mgmt. Sci. 61, 64 (2002) (finding that faculty involvement was important to seven out of eleven cases studies of technology transfer).

[128] Thursby & Thursby, *supra* note 64, at 167.

[129] *Id*. at 170; Nicholas S. Argyres & Julia Porter Liebeskind, *Privatizing the Intellectual Commons: Universities and the Commercialization of Biotechnology*, 35 J. Econ. Behav. & Org. 427, 450 (1998); *see* Thomas Hellmann, *The Role of Patents for Bridging the Science to Market Gap*, 63 J. Econ. Behav. & Org. 624, 627 (2007); *see also* Howells, *supra* note 18, at 95.

[130] Faculty members may be particularly motivated to consult on projects related to their patents to supplement rather limited patent-related royalties. *See* Bercovitz & Feldmann, *supra* note 64, at 179 (noting the relatively small after-tax returns on royalties compared to consulting).

[131] *See* Pisano, *Can Science Be a Business?*, *supra* note 17, at 2.

[132] Lynne G. Zucker & Michael R. Darby, *Star Scientists and Institutional Transformation: Patterns of Invention and Innovation in the Formation of the Biotechnology Industry*, 93 Proc. Nat'l Acad. Sci. U.S. Am. 12,709, 12,712 (1996).

[133] Zucker et al., *Commercializing Knowledge*, *supra* note 12, at 149; *see* Zucker et al., *Intellectual Human Capital*, *supra* note 54; Zucker & Darby, *supra* note 132, at 12,709.

[134] Siegel et al., *supra* note 75, at 118; *see* Kenney, *supra* note 122, at 149–54 (discussing biotechnology Scientific Advisory Boards).

[135] Tamar Lewin, *The Patent Race in Gene-Splicing*, N.Y. Times, Aug. 29, 1982, *available at* http://www.nytimes.com/1982/08/29/business/the-patent-race-in-gene-splicing.html (last visited Oct. 17, 2019); *see* Sally Smith Hughes, *Making Dollars Out of DNA*: *The First Major Patent in Biotechnology and the Commercialization of Molecular Biology, 1974–1980*, 92 Isis 541, 562 (2001) ("What raised concern in Cohen's case was the fact that he was an inventor on a Stanford patent application and at the same time a paid consultant for a company seeking a license on the invention being patented."); Kenney, *supra* note 122, at 94 ("Genentech was presumably started on Boyer's consulting time while he was a professor at the UCSF Medical Center.").

as attracting venture capital and shareholder investment[136]—it also facilitates the transfer of tacit knowledge. The importance of engaging faculty inventors in commercializing university discoveries is not unique to the biotechnology industry and extends to other technical fields, like semiconductors.[137] In sum, the participation of faculty scientists plays an important role in bringing academic discoveries to market.[138]

## C. Sponsored Research

Another mechanism by which tacit technical knowledge flows from academic to industrial scientists is sponsored research.[139] In such arrangements, companies fund research at universities and exercise varying levels of control over the research and its outputs, which may include patented inventions. For example, as far back as 1974, Monsanto entered into a 12-year agreement to provide $23 million in research and endowment support to Harvard Medical School in exchange for the rights to any patents that arose from research on a substance related to cancer growth.[140] Declining federal support has led universities to rely more heavily on sponsored research, which has also led them to "focus more on knowledge transfer issues that provide value to the sponsoring firm."[141]

Sponsored research serves several objectives, some of which directly implicate tacit knowledge. Close ties between a corporate sponsor and a university can allow industry personnel to become aware of commercially promising research even before a university begins marketing it.[142] More generally, funding university research exposes a corporate sponsor to the latest science, which enhances its absorptive capacity.[143] Furthermore, it allows companies to exploit the technical expertise and infrastructure of universities to pursue research with potential commercial applications. Relatedly, as with the Monsanto-Harvard Medical School deal, sponsors may obtain patent rights on valuable research outputs.[144] Along the way, sponsored research often involves joint research between academic and corporate scientists, thus facilitating tacit knowledge transfer.[145] Sponsored research is particularly well-suited for providing access to university inventions that are too embryonic to patent and license.[146] In sum, sponsored

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136 In the early biotech industry, IPO prospectuses often highlighted the participation of notable academic scientists. Zucker et al., *Commercializing Knowledge*, *supra* note 12, at 143.

137 Zucker & Darby, *supra* note 132, at 12,715.

138 *Id*.

139 Bercovitz & Feldmann, *supra* note 64, at 177.

140 Barbara J. Culliton, *Harvard and Monsanto: The $23-Million Alliance*, 4280 Science 759, 759 (1977).

141 Michael D. Santoro & Paul E. Bierly, III, *Facilitators of Knowledge Transfer in University-Industry Collaborations: A Knowledge-Based Perspective*, 53 IEEE Transactions Engineering Mgmt. 495, 495 (2006).

142 Colyvas et al., *supra* note 127, at 66–67.

143 *See supra* note 108 and accompanying text.

144 *See* Kenney, *supra* note 122, at 58.

145 Iain Cockburn & Rebecca Henderson, *Absorptive Capacity, Coauthoring Behavior and the Organization of Research in Drug Discovery*, 46 J. Indus. Econ. 157, 166 (1998); Link et al., *supra* note 125, at 645; David Blumenthal, *Academic-Industrial Relationships in the Life Sciences*, 349 New Eng. J. Med. 2452, 2454 (2003).

146 Thursby & Thursby, *supra* note 64, at 163.

research allows corporations to maintain relationships with faculty inventors whose inventions they are licensing or seek to license.[147]

Sponsored research often blurs the institutional boundaries between the corporate sponsor and the university it funds.[148] For example, when Hoechst sponsored research at Massachusetts General Hospital, one commentator observed that scientists at the hospital "might well come to believe that they work for Hoechst."[149] Additionally, sponsored research may involve embedding corporate scientists in university laboratories.[150] Sponsored research has led to new institutions that bridge academic and industrial partners. For instance, the Whitehead Institute for Biomedical Research at MIT, which is financed by biotech venture capitalist and major Revlon shareholder Edwin Whitehead,[151] reflects "an attempt to create an inter-penetrating system of public and private research within a university setting."[152] Further blurring institutional boundaries, sponsored research tends to lead to more sponsored research. At UC Irvine, corporate research sponsors can receive not just exclusive licenses to patented inventions but also the right to sponsor further research in related areas.[153] Additionally, about a third of university licenses require compensation by the licensee in the form of sponsored research,[154] and licensing for sponsored research represents the predominant licensing strategy for 11% of TTOs.[155] Sponsored research helps maintain interactions—and, in some cases, institutional meshing—between universities and corporate entities, which promotes tacit knowledge exchange.

### D. Proof of Concept Centers and Incubators

In addition to direct contacts between university inventors and licensees, universities often create more enduring institutional connections with commercial entities to serve several functions, including transferring tacit knowledge. For example, many universities have established proof of concept centers, which "are becoming an important vehicle for advancing technology commercialization."[156] These centers nurture commercialization relatively early in the development chain, earlier than traditional business incubators.[157] Proof of concept centers provide

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[147] *Id*. at 175.

[148] *Cf*. Etzkowitz & Viale, *supra* note 2, at 602 (discussing permeable boundaries between academic and private entities).

[149] Nicholas Wade, *The Science Business: Report of the Twentieth Century Fund Task Force on the Commercialization of Scientific Research* 48 (1984).

[150] Murray, *supra* note 64, at 654.

[151] Argyres & Liebeskind, *supra* note 129, at 448.

[152] *Id*.

[153] *Id*. at 444.

[154] Jensen & Thursby, *supra* note 65, at 246.

[155] Gideon D. Markman et al., *Entrepreneurship and University-based Technology Transfer*, 20 J. Bus. Venturing 241, 251 (2005).

[156] Christopher S. Hayter & Albert N. Link, *On the Economic Impact of University Proof of Concept Centers*, 40 J. Tech. Transfer 178, 179 (2015) [hereinafter Hayter & Link, *Economic Impact*].

[157] Bob Tedeschi, *The Idea Incubator Goes to Campus*, N.Y. Times, June 27, 2010, at BU1; *see* Ewing Marion Kauffman Foundation, *Proof of Concept Centers: Accelerating the Commercialization of University Innovation* (2008) (discussing the Deshpande Center at MIT and the von Liebig Center at the University of California San Diego).

a range of resources, services and networks to help university startups.[158] While the primary function of proof of concept centers is to provide funding, they also promote knowledge exchange between university innovators and industry via various mentors.[159] For example, the von Liebig Center at UCSD provides technical advisors to participants, and the Deshpande Center at MIT provides volunteer advisors to serve as catalysts with industry.[160] Interestingly, in addition to helping to transfer tacit technical knowledge to industry, such proof of concept centers allow advisors to transfer tacit business knowledge to faculty inventors. By 2012, over 30 proof of concept centers had been established in the United States.[161]

Further downstream in the development chain, universities have also created incubators to facilitate the commercialization of academic technologies.[162] Such entities "are property-based organizations with identifiable administrative centers focused on the mission of business acceleration through knowledge agglomeration and resource sharing."[163] They provide social, technological, organizational and managerial resources to help transform technology-based business ideas into sustainable enterprises.[164] Many universities are establishing incubators to promote commercialization of academic technologies;[165] in one study, 62% of universities surveyed report that they are establishing incubators and research parks.[166] One of the functions of incubators is to promote interactions and working relationships between academic scientists and entrepreneurs,[167] which can facilitate tacit knowledge transfer. Closely related to incubators are university research parks, agglomerations of resources and businesses that foster the creation of startups based on university technologies.[168] Due to the institutional and often geographic proximity of research parks and universities, firms located in such parks have greater opportunities to obtain tacit knowledge from academic scientists.[169] These parks "enhance the two-way flow of knowledge between firms and universities,"[170] thus promoting commercialization.

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[158] Hayter & Link, *Economic Impact*, *supra* note 156, at 179.

[159] Christine A. Gulbranson & David B. Audretsch, *Proof of Concept Centers: Accelerating the Commercialization of University Innovation*, 33 J. Tech. Transfer 249, 250 (2008).

[160] *Id*. at 252–3; Hayter & Link, *Economic Impact*, *supra* note 156, at 179.

[161] Christopher S. Hayter & Albert N. Link, *University Proof of Concept Centers: Empowering Faculty to Capitalize on Their Research*, Issues in Sci. & Tech., Winter 2005, at 35.

[162] Phillip H. Pan et al., *Science Parks and Incubators: Observations, Synthesis and Future Research*, 20 J. Bus. Venturing 165, 167–8 (2005).

[163] *Id*., at 166.

[164] *Id*. at 170–71; Rosa Grimaldi et al., *30 Years after Bayh-Dole, Reassessing Academic Entrepreneurship*, 40 Res. Pol'y 1045, 1048 (2011).

[165] *See* Annetine C. Gelijns & Samuel O. Thier, *Medial Innovation and Institutional Interdependence*, 287 JAMA 72, 75 (2002); Markman et al., *supra* note 155, at 244–5 (describing the Rensselaer Polytechnic Institute incubator); *id*. at 252 (noting that 62% of TTOs devoted significant resources to building business incubators); Tedeschi, *supra* note 157.

[166] Markman et al., *supra* note 155, at 242.

[167] Dante Di Gregorio & Scott Shane, *Why Do Some Universities Generate More Start-Ups Than Others?*, 32 Res. Pol'y 209, 213 (2003); Grimaldi et al., *supra* note 164, at 1048.

[168] Albert N. Link & John T. Scott, *The Economics of University Research Parks*, 23 Oxford Rev. Econ. Pol'y 661, 661 (2007).

[169] *Id*. at 664.

[170] *Id*. at 670.

### E. University Spinoffs

Another mechanism to transfer tacit knowledge from universities to commercial entities is to integrate academic and commercial functions in a university spinoff. In the 1990s, Stanford faculty began starting companies, and Stanford granted a significant number of licenses to "university spinoffs or startups where Stanford inventors hold key executive positions or serve on scientific advisory boards."[171] In a common pattern, a faculty inventor will assign her patents to a university (based on her employment agreement), and the university will then license those patents to a startup founded by the faculty inventor. Several universities extend preferential treatment to university inventors seeking to license their own inventions to start companies.[172] More broadly, "[u]niversity spin-offs have become a favored mechanism by which universities transfer technology to the commercial realm."[173]

The organizational form of a university spinoff is well suited to transfer tacit knowledge. According to one observer, "[s]tart-ups internalize the full set of interactions between research and productive organizations that lead to the successful development of a commercial product; the full set includes many more things transacted other than patents," including tacit knowledge.[174] Due to the highly tacit nature of much cutting-edge scientific knowledge, university scientists are best situated to exploit it commercially, and they are perhaps the only persons capable of doing so.[175] Indeed, one theoretical model posits that university spinouts established by faculty inventors will be the sole vehicle for commercializing inventions with a significant tacit dimension.[176] In many spinoffs, academic expertise and commercial functions are integrated when a faculty inventor establishes a new company.[177] Entrepreneurial university scientists who participate in commercialization help minimize gaps in tacit knowledge.[178] Furthermore, empirical studies reveal that star academic scientists frequently played a critical role in establishing new biotechnology companies.[179]

Just as university spinoffs are well-positioned to exploit tacit knowledge, such knowledge is often critical to their success.[180] An empirical examination of spinoffs from a leading technical

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171 Jeannette A. Colyvas & Walter W. Powell, *Roads to Institutionalization: The Remaking of Boundaries between Public and Private Science*, 27 Res. Org. Behav. 305, 343 (2018); *see also* Etzkowitz & Viale, *supra* note 2, at 597.

172 Grimaldi et al., *supra* note 164, at 1049. For instance, the University of North Carolina at Chapel Hill has created an Express Licensing Agreement that expedites licensing to faculty inventors seeking to commercialize their inventions. *Id*.

173 Bercovitz & Feldmann, *supra* note 64, at 179; *see also* Etzkowitz & Viale, *supra* note 2, at 600 (describing the emergence of the "entrepreneurial university" that generates spinoffs).

174 Walter D. Valdivia, *University Start-Ups: Critical for Improving Technology Transfer* 18 (2013).

175 Di Gregorio & Shane, *supra* note 167, at 212; *see* Robert A. Lowe, *Who Develops a University Invention? The Impact of Tacit Knowledge and Licensing Policies*, 31 J. Tech. Trans. 420 (2006).

176 Lowe, *supra* note 175, at 415.

177 *Cf.* Andy Lockett et al., *Technology Transfer and Universities' Spin-Out Strategies*, 20 Small Bus. Econ. 185, 186, 196 (2003).

178 Etzkowitz & Viale, *supra* note 2, at 600.

179 Zucker & Darby, *supra* note 132, at 12,713; Powell, *supra* note 116, at 200. According to one observer, "The pervasive role of professors in managing and directing [biotechnology] startups is unique in the annals of business history." Kenney, *supra* note 122, at 4; *see id.* at 94 ("All of the earliest genetic engineering companies were founded by professors."); *see id*. at 98 (listing the involvement of founding professors with various companies).

180 Knockaert et al., *supra* note 43, at 780.

university in Belgium showed that "effective tacit knowledge transfer was crucial" for the performance of science-based entrepreneurial firms.[181] For spinoffs where the faculty inventor is not the principal entrepreneur, the inventor's participation in commercialization is often critical to success.[182] Empirical research has found that "[s]uccessful knowledge transfer is more likely if the original scientists who worked on developing the technology are also involved in the venture."[183] Furthermore, it found that a critical mass of tacit knowledge was necessary, which included employing the majority of initial researchers.[184]

## IV. RETHEORIZING UNIVERSITY LICENSING AND TECHNOLOGY TRANSFER

The centrality of tacit knowledge to effective commercialization of academic technologies raises a host of implications for university-industry technology transfer. First, it underscores that technology transfer is much more than simply patenting and licensing university inventions.[185] As this Chapter has demonstrated, a rich set of human and institutional connections is often necessary in parallel to licensing to effectively transfer and commercialize a patented academic invention. Relatedly, the centrality of tacit knowledge also calls into question traditional metrics for measuring the effectiveness of technology transfer. The so-called "out-the-door" criterion focuses on whether a technology has been converted to some kind of transfer mechanism, such as a license, which another party has acquired.[186] This criterion, however, does not inquire into what the receiving entity *does* with the technology, and in the absence of technology-related tacit knowledge, it may not be able to do much at all.

Second, the importance of tacit knowledge flows helps explain a distinctive characteristic of university-industry technology transfer: its highly localized nature. We have seen that tacit knowledge transmission often requires direct interpersonal interaction; not surprisingly, tacit knowledge tends to be geographically concentrated around the location of a discovery.[187] Similarly, empirical studies illustrate the importance of proximity in capturing knowledge spillovers from universities,[188] and commercialization of university inventions tends to be localized around the place of invention.[189] Even though universities can license their patents nationally (or globally), university-based entrepreneurship tends to be decidedly local.[190] Of course, several factors contribute to this geographic proximity, such as connections between TTO personnel and local businesses as well as universities' commitments to foster local economic development. Nonetheless, the need to transfer tacit knowledge and interact directly

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181 *Id*. at 784.
182 Lockett et al., *supra* note 177, at 187.
183 Knockaert et al., *supra* note 43, at 788.
184 *Id*. at 789.
185 Valdivia, *supra* note 174, at 5 ("Technology transfer is thus not a matter of patents alone; rather it is the complex work that takes place at the interface of research and productive organizations.").
186 Bozeman et al., *supra* note 105, at 37
187 Zucker et al., *Commercializing Knowledge*, *supra* note 12, at 142.
188 Adam B. Jaffe et al., *Geographical Localization of Knowledge Spillovers as Evidenced by Patent Citations*, Q.J. Econ. 577 (1993).
189 Agrawal, *Knowledge Transfer*, *supra* note 64, at 301.
190 Bercovitz & Feldmann, *supra* note 64, at 179.

with faculty inventors plays a role as well: "When university-based scientists are actively involved in knowledge transfer, their knowledge is more easily tapped if the firm is located in the same region as the scientist."[191]

Third, the importance of tacit knowledge to practicing university inventions challenges traditional rationales for patenting such technologies in the first place. This Chapter has focused on tacit knowledge transfers in parallel to formal patenting and licensing. The central narrative of patents justifies exclusive rights to protect against costless appropriation of an otherwise nonrival, nonexcludable resource.[192] However, tacit knowledge is naturally excludable,[193] and the highly tacit nature of some embryonic university inventions lessens the need to patent them to safeguard against unauthorized appropriation. As Dan Burk observes, "codified knowledge, having been separated from human memory, may be more readily moved about, but the uncodified knowledge that supports this codified knowledge moves only with the humans who carry it, or sometimes not at all."[194] Ultimately, the centrality of tacit knowledge calls into question the rationale for patenting certain cutting-edge university inventions.

Fourth, while the need to transfer tacit knowledge fuels greater connections between individual scientists and companies, it also motivates broader institutional integration between universities and companies, thus blurring the boundaries between these historically distinct institutions. In understanding such organizational integration, the knowledge-based theory of the firm provides useful insight. In classic articulations of the theory of the firm, integrated firms emerge as a solution to transaction costs and opportunism that plague contractual relationships between independent entities.[195] In the context of technology transactions, patents can ameliorate these contractual hazards, thus facilitating contracting between separate parties.[196] However, patents do not disclose and licenses do not convey critical tacit knowledge necessary to commercialize many patented technologies. In the realm of university-industry technology transfer, this knowledge deficit has motivated a host of institutional connections spanning sponsored research agreements, proof of concept centers, incubators and spinoffs. Such integration implicates the knowledge-based theory of the firm, which characterizes integrated organizations not as solutions to contractual hazards and opportunistic behavior[197] but as solutions for the challenges of accessing, collecting and exploiting knowledge.[198] After all, "[c]ommunication between R&D and manufacturing flows more easily when the organizations share common experiences and information systems."[199] Ultimately, organizational integration between academic and commercial entities may be the most effective means of transferring tacit knowledge and promoting commercialization. This finding, moreover, is rather startling given the stark normative and cultural differences between those types of institutions.[200]

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191 Audretsch & Stephan, *supra* note 84, at 644.
192 Lee, *Transcending*, *supra* note 98, at 1570.
193 Zucker et al., *Commercializing Knowledge*, *supra* note 12, at 141.
194 Burk, *supra* note 14, at 1017.
195 *See, e.g.*, Benjamin Klein et al., *Vertical Integration, Appropriable Rents, and the Competitive Contracting Process*, 21 J.L. & Econ. 297 (1978).
196 Lee, *Innovation and the Firm*, *supra* note 23, at 1439–42.
197 Powell et al., *supra* note 93, at 117–18.
198 Knockaert et al., *supra* note 43, at 780; Powell et al., *supra* note 93, at 118.
199 Pisano et al., *supra* note 20, at 199 (citation omitted).
200 Lee, *Transcending*, *supra* note 98, at 1511.

Fifth and relatedly, tighter connections between academic and commercial entities raise normative concerns about compromising traditional academic norms. The naturally excludable character of tacit knowledge enhances the commercial value of faculty inventors (and their tacit knowledge) and may encourage faculty members to pursue more commercially lucrative rather than scientifically meritorious lines of research. In biotechnology, for example, increases in the quality and commercial relevance of the work of star scientists are correlated with an increased probability of conducting joint research with or joining a commercial entity.[201] Close collaborations with companies raise concerns of "increased opportunity for conflicts of interest, redirection of research, less openness in sharing of scientific discovery, and a greater emphasis on applied rather than basic research."[202] At a broader institutional level, organizational integration between universities and profit-maximizing firms calls into question universities' commitment to disinterested academic inquiry and basic research with no immediate commercial applications. While research suggests that traditional scientific norms have not eroded and that universities are not performing less basic research,[203] greater proximity of academic and commercial entities may change the normative identity of scientists and universities over time.

## V. CONCLUSION

This Chapter has explored the importance of tacit knowledge in university-industry technology transfer. Discussions of technology transfer often focus on patenting and licensing, which is certainly important to commercializing academic technologies. However, this Chapter has highlighted the significance of noncodified, experiential, tacit knowledge on the part of university inventors in transferring technologies to the private sector. Patents do not disclose tacit knowledge, which can run the gamut from latent knowledge that is codifiable but not codified to pure tacit knowledge, which is not capable of codification. The tacit dimension of an invention depends on the nature and complexity of a technology, and it tends to decrease over time as personal knowledge diffuses and becomes more accessible. Tacit knowledge is valuable not only for practicing some basic invention but also for adapting it to industrial use and commercial production. Transferring such knowledge is very difficult and often requires direct interpersonal interaction between a faculty inventor and a commercial licensee.

Accordingly, this Chapter has also explored several relational and institutional mechanisms for transferring tacit knowledge. Networks, consulting agreements and corporate positions, sponsored research, proof of concept centers and incubators, and university spinoffs all facilitate greater engagement between faculty inventors and commercial partners, which promotes tacit knowledge exchange. These observations simply underscore the reality that "[u]niversity patents represent only one mechanism by which academic research results can be transferred

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201 Lynn G. Zucker et al., *Labor Mobility from Academe to Commerce*, 20 J. Labor. Econ. 629 (2001).

202 Wendy H. Schacht, *The Bayh-Dole Act: Selected Issues in Patent Policy and Commercialization of Technology*, 13 Cong. Res. Serv. (2012); *see* Perkmann et al., *supra* note 112, at 428.

203 Grimaldi et al., supra note 164, at 1046; *see also* Kira R. Fabrizio & Alberto Di Minin, *Commercializing the Laboratory: Faculty Patenting and the Open Science Environment*, 37 Res. Pol'y 914, 916 (2008) (finding a positive correlation between patenting and publishing that declines with the increasing number of cumulative patents attributed to a faculty inventor).

to the market place."[204] Furthermore, the importance of direct personal interactions with inventors helps explain the geographically localized nature of university-industry technology transfer. Greater engagement between faculty members and university with commercial partners can accelerate tacit knowledge exchange and technology transfer, but it raises concerns over altering traditional academic research norms and priorities. Ultimately, conveying tacit knowledge represents a central challenge of university-industry technology transfer.

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204 Grimaldi et al., *supra* note 164, at 1047.