PATENT LAW AND THE SOCIOLOGY OF INNOVATION

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Francis Bacon stressed centuries ago that innovation is inevitably influenced by mental and social constraints. It is only by exposing and understanding these constraints, Bacon argued, that society can fully benefit from scientific innovation. But while historians and sociologists of science and technology have long appreciated how institutional norms shape the course, pace, and content of innovation, legal scholarship on patent law has all but ignored this insight. In this Article, I seek to complement traditional law and economic analyses of patent law by developing a sociological and historical approach that focuses in concrete detail on the ways in which scientific knowledge, and thus innovation, is made, maintained, and modified. Drawing from sociological analysis of historical case studies of innovation, I focus on factors that affect the timing of innovation. I argue that understanding why some scientific advances and innovations take a long time to develop or be recognized and endorsed by the scientific community provides an opportunity to reshape patent law as a policy lever to mitigate such delays. Conversely, understanding why other types of innovation occur rapidly and spark swift follow-on innovation suggests circumstances in which broad patent rights may impose particularly high social costs.

This socio-historical approach is responsive to recent Supreme Court patent law jurisprudence, exemplified by *KSR v. Teleflex*, that directs courts to take a flexible approach to patentability by considering "the circumstances surrounding the origin of the invention." By teasing out social factors that influence the pace of innovation, I offer a framework for taking such considerations into account in the design and application of patent law. I also propose specific changes to patent law doctrine that flow from this framework.

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INTRODUCTION

> *Science sometimes sees itself as impersonal, as "pure thought," independent of its historical and human origins. . . . But science is a human enterprise through and through, an organic, evolving, human growth, with sudden spurts and arrests, and strange deviations, too.*
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> —Oliver Sacks[1]

> *[M]ore sophisticated social and historical analysis [of innovation] can aid both the institution of science and the work of scientists . . . by encouraging study and scrutiny of the social contexts that channel our thinking and the attracted and innate biases (Bacon's idols) that frustrate our potential creativity.*
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> —Stephen Jay Gould[2]

Francis Bacon, widely considered the father of the modern scientific method, stressed centuries ago that innovation is inevitably influenced by mental and social constraints.[3] It is only by exposing and understanding these constraints, Bacon argued, that society can fully benefit from scientific innovation.[4] In the landmark United States Supreme Court decision *KSR International Co. v. Teleflex Inc.*,[5] Justice Anthony Kennedy echoed Bacon's concern about the context of invention by

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1. Robert Silvers, *Introduction* to HIDDEN HISTORIES OF SCIENCE at i (Robert B. Silvers ed., 1995) (quoting Oliver Sacks).

2. Stephen Jay Gould, *Deconstructing the "Science Wars" by Reconstructing an Old Mold*, 287 SCIENCE 253, 261 (2000).

3. *See* FRANCIS BACON, OF THE ADVANCEMENT AND PROFICIENCIE OF LEARNING: OR THE PARTITIONS OF SCIENCES, NINE BOOKS 17–21 (Gilbert Wats. trans., 1674).

4. *Id.* Bacon is most often remembered for his defense of empirical observation and for his rejection of unquestioned obedience to ancient authority. Gould, *supra* note 2, at 254. To successive generations of scientists, Bacon came to represent the ideal of scientific objectivity free of distorting social bias. *See id.* Nevertheless, Bacon was well aware that social and ideological biases (which he termed "idols") influenced scientific exploration. *Id.* at 254–55. According to Bacon, the influence of two kinds of idols—"innate" or arising from within the individual, and "attracted" or derived from external social influences—on scientific research needed to be exposed. *Id.* at 255. Their influence, however, could be reduced but not entirely eliminated: the scientific quest was "an interplay of mental foibles and outside facts, not an objective march to truth—a marriage of our mental propensities with nature's realities." *Id.*; *see also* Moody E. Prior, *Bacon's Man of Science*, *in* THE RISE OF SCIENCE IN RELATION TO SOCIETY 42 (Leonard M. Marsak ed., 1964) (describing how the members of the Royal Society of Science thought of Bacon as their "patron saint").

5. 550 U.S. 398 (2007).

directing courts to take a flexible approach to patentability that takes into account "the circumstances surrounding the origin of the [invention]."[6] In so doing, the Court implicitly recognized the importance of a sociological understanding of innovation. Indeed, sociologists of science and technology have long appreciated that institutional norms and practices shape the course, pace, and content of innovation.[7] Legal scholarship on patent law—focused largely on market incentives to innovate—has paid remarkably little attention to these insights.

This Article contends that understanding the background social forces that influence innovation is crucial for patent law to better fulfill its constitutional mandate to "promote the Progress of Science and useful Arts."[8] A socio-historical approach to patent law, rooted in the sociological and historical study of scientific innovation, is essential for three reasons. First, if the primary goal of patent law is to incentivize innovation,[9] it is important to understand how innovation is both

6. *Id.* at 399 (quoting *Graham v. John Deere Co.*, 383 U.S. 1, 17–18 (1966)). *KSR* addressed the obviousness doctrine, which has been alternately referred to as "the defining feature of invention," "the ultimate condition of patentability," "the final gatekeeper of the patent system," and "the heart of the patent law." John F. Duffy, *Inventing Invention: A Case Study of Legal Innovation*, 86 TEX. L. REV. 1, 2 (2007) (citations omitted).

7. Historians and sociologists of science are not necessarily of a piece in their analysis of the social determinants of innovation. Indeed, an important chapter in the history of the sociology of science is what has been termed the "Science Wars," that pitted sociologists of the "sociology of knowledge" or "social constructivist" school against more traditional sociologists and scientists. *See* Gould, *supra* note 2, at 253. I adopt a science and technology studies (STS) approach, which relies on interdisciplinary social studies methods to study innovation (for example, using sociology, anthropology, and history). I focus primarily on sociological analyses of historical case studies of innovation. For ease of referencing, I have termed this approach a "socio-historical" approach to innovation. See Part II for a brief historical background on the emergence and development of the science and technology studies field.

8. U.S. CONST. art. I, § 8, cl. 8.

9. The standard justification for granting patent rights to the products of innovation is utilitarian: the function of patent law is to ex ante stimulate innovation. *See, e.g.*, FRITZ MACHLUP, AN ECONOMIC REVIEW OF THE PATENT SYSTEM, STUDY NO. 15, SUBCOMM. ON PATENTS, TRADEMARKS, AND COPYRIGHTS OF THE S. COMM. ON THE JUDICIARY, 85TH CONG. 2D SESS. 1, 33 (1958) ("The thesis that the patent system may produce effective profit incentives for inventive activity and thereby promote progress in the technical arts is widely accepted."); Mark A. Lemley, *Property, Intellectual Property, and Free Riding*, 83 TEX. L. REV. 1031, 1031 (2005). A second utilitarian justification for patent rights, grounded on property theory, understands patents as "prospects" that encourage the efficient management of technological innovation. *See* Edmund W. Kitch, *The Nature and Function of the Patent System*, 20 J.L. & ECON. 265, 265–66, 268 (1977); John F. Duffy, *Rethinking the Prospect Theory of Patents*, 79 U. CHI. L. REV. 439, 446 (2004) (explaining the "prospect" features of the patent system not as a coordination or management mechanism but as promoting "earlier patenting and thus earlier dedication to the public"). There are also nonutilitarian justifications for intellectual property,

constrained and facilitated by the institutional contexts in which it takes place. Second, such an approach would enable patent law to better reflect the realities of how innovation actually happens—an important objective of patent law, which assesses patentability from the vantage point of a "person of ordinary skill in the art."[10] Third, it can provide answers to key questions that arise from the Court's directive in *KSR* to take a functional approach to patentability, among them: How should the origin of an invention affect patentability? And which circumstances are relevant and why?

A fundamental tenet of patent law is that patents should only be granted to those inventions that would not be developed or whose development would be significantly delayed absent patent protection.[11] When market competition is sufficient to stimulate innovation, monopoly pricing arising from patent protection would only lead to unnecessary social cost.[12] Thus, a key function of patent doctrine is to weed out those inventions whose protection would only act as a tax to future innovators from those that are worth the "embarrassment of an exclusive patent."[13]

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although these justifications have tended to play only a secondary role in the development of patent law. *See, e.g.*, Justin Hughes, *The Philosophy of Intellectual Property*, 77 GEO. L.J. 287 (1988); Seana Valentine Shiffrin, *Lockean Arguments for Private Intellectual Property*, *in* NEW ESSAYS IN THE LEGAL AND POLITICAL THEORY OF PROPERTY 138, 152 (Stephen R. Munzer ed., 2001).

10. *See KSR*, 550 U.S. at 418 (directing courts to "take account of the inferences and creative steps that a person of ordinary skill in the art would employ"). Although a person having ordinary skill in the art (PHOSITA) is a "hypothetical person" and an "imaginary being," which has been likened to the "reasonable person" of tort law, I argue that such a hypothetical person should incorporate an understanding of how real-world social constraints contribute to innovation delays or innovative fruitfulness. *See* Michael Abramowicz & John F. Duffy, *The Inducement Standard of Patentability*, 120 YALE L.J. 1590, 1605 (2011) (citations omitted). Such an understanding of a PHOSITA both responds and gives content to the Court's ruling in *KSR*, which emphasized a realistic, case-by-case approach to patentability. *See, e.g.*, Daralyn J. Durie & Mark A. Lemley, *A Realistic Approach to the Obviousness of Inventions*, 50 WM. & MARY L. REV 989, 1000–03 (2008) (arguing that, in the aftermath of *KSR*, courts should pay increased attention to "the way in which PHOSITAs work in the real world").

11. *See, e.g.*, Lemley, *supra* note 9, at 1031 (describing the "long-standing view" that intellectual property rights should be granted "only when—and only to the extent that—they are necessary to encourage invention"); Abramowicz & Duffy, *supra* note 10, at 1599.

12. Lemley, *supra* note 9, at 1060–62; *see also* Christopher A. Cotropia, *Nonobviousness and the Federal Circuit: An Empirical Analysis of Recent Case Law*, 82 NOTRE DAME L. REV. 911, 916 (2007).

13. *Graham v. John Deere Co.*, 383 U.S. 1, 8–9 (1966) (quoting Letter from Thomas Jefferson to Isaac M'pherson (Aug. 18, 1813), *in* 6 WRITINGS OF THOMAS JEFFERSON 175, 180–81 (H.A. Washington ed., 1854)); *see* Nancy Gallini & Suzanne Scotchmer, *Intellectual Property: When Is It the Best Incentive System?*, *in* 2 INNOVATION POLICY AND THE ECONOMY (Adam B. Jaffe et al. eds., 2002) (noting that a key question in

It is through the obviousness doctrine, whose application was under dispute before the Supreme Court in *KSR*, that patent law seeks to operationalize this balancing act.[14] As "the final gatekeeper of the patent system,"[15] the obviousness doctrine requires patentable inventions to represent more than minor improvements to existing technology that would likely arise through routine research as a response to market pressures.[16] But assessments of whether an invention is worthy of patent protection—which, at the litigation stage, are often made years after the initial discovery—are susceptible to hindsight bias against patentability.[17] Federal Circuit jurisprudence prior to *KSR* sought to minimize the risk of hindsight bias by recourse to the "teaching, suggestion, or motivation" (TSM) test.[18] The TSM test required not only a demonstration that an invention could theoretically be reconstructed as the combination of two or more pre-existing references but also a showing of some overt "teaching, motivation, or suggestion" that would

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designing an intellectual property regime is "[h]ow should intellectual property be designed so as to minimize deadweight loss due to monopoly pricing without undermining incentives to innovate?" and reviewing the economic literature on intellectual property law as an incentive to innovate); Kenneth W. Dam, *The Economic Underpinnings of Patent Law*, 23 J. LEGAL STUD. 247, 253 (1994) (arguing that patent law faces the problem of finding an "economically optimal balance between innovation today and innovation tomorrow"). Present-day economists' concerns with designing a patent system to foster innovation while minimizing the social cost resulting from monopoly pricing date back to William Nordhaus's 1969 work, which justified a finite length of patent protection as balancing these two competing concerns. WILLIAM D. NORDHAUS, INVENTION, GROWTH, AND WELFARE: A THEORETICAL TREATMENT OF TECHNOLOGICAL CHANGE ch. 5 (1969). But concerns that patent law may stifle innovation and slow progress were already salient in the nineteenth century. *See, e.g.*, Fritz Machlup & Edith Penrose, *The Patent Controversy in the Nineteenth Century*, 10 J. ECON. HIST. 1, 3–5 (1950).

14. 35 U.S.C. § 103(a) (2006 & Supp. V 2011) ("Conditions for patentability; nonobvious subject matter: A patent for a claimed invention may not be obtained, notwithstanding that the claimed invention is not identically disclosed as set forth in section 102, if the differences between the claimed invention and the prior art are such that the claimed invention as a whole would have been obvious before the effective filing date of the claimed invention to a person having ordinary skill in the art to which the claimed invention pertains. Patentability shall not be negated by the manner in which the invention was made.").

15. ROBERT PATRICK MERGES & JOHN FITZGERALD DUFFY, PATENT LAW AND POLICY 620 (5th ed. 2011).

16. *See, e.g.*, Duffy, *supra* note 6, at 6–7.

17. *See, e.g.*, *Brown & Williamson Tobacco Corp. v. Philip Morris Inc.*, 229 F.3d 1120, 1126 (Fed. Cir. 2000); *In re Dembiczak*, 175 F.3d 994, 999 (Fed. Cir. 1999); *see also* Gregory N. Mandel, *Patently Non-obvious: Empirical Demonstration That the Hindsight Bias Renders Patent Decisions Irrational*, 67 OHIO ST. L.J. 1391 (2006).

18. *See KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398, 421 (2007) (describing the TSM test as attempting to guard against hindsight bias).

have led a skilled artisan in the field of the invention to make such a combination.[19] The Court in *KSR* rejected the Federal Circuit's "rigid approach" to patentability and embraced instead a flexible approach that replaced the TSM test with an individualized case-by-case assessment of what practitioners in that particular field would likely be able to develop through routine research.[20]

The contextual, case-by-case inquiry required by the Court in *KSR* compels an understanding of how the institutional contexts in which innovation takes place could either constrain or accelerate innovation. Law and economics approaches to patent law, however, tend to treat social contexts as a black box, even as they recognize the crucial importance of identifying those circumstances that would affect the timing of invention.[21] Indeed, the majority of patent law scholarship does not engage with the context of scientific research or technological innovation, or with the social and institutional determinants to innovation, but rather relies on linear models to describe the process of innovation as proceeding through a series of predetermined steps.[22] This approach is incomplete, as it is not only market forces, but also social forces, that hinder or accelerate innovation.

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19. *See, e.g.*, *In re Lee*, 277 F.3d 1338, 1343–45 (Fed. Cir. 2002).

20. *KSR*, 550 U.S. at 415–22.

21. *See, e.g.*, WILLIAM M. LANDES & RICHARD A. POSNER, THE ECONOMIC STRUCTURE OF INTELLECTUAL PROPERTY LAW 304 (2003); Abramowicz & Duffy, *supra* note 10, at 1599 (Michael Abramowicz and John Duffy develop an inducement standard of patentability that requires patents "to cover only those inventions that, but for the inducement of a patent, would not have be[en] disclosed or devised *for a substantial period of time*." (emphasis added)); Edmund W. Kitch, Graham v. John Deere*: New Standards for Patents*, 1966 SUP. CT. REV. 293, 301 (stating that "a patent should not be granted for an innovation unless the innovation would have been unlikely to have been developed absent the prospect of a patent"); Robert P. Merges, *Uncertainty and the Standard of Patentability*, 7 HIGH TECH. L.J. 1 (1992) (explaining nonobviousness as a legal rule that "seeks to reward inventions that, viewed prospectively, have a low probability of success"); Michael J. Meurer & Katherine Strandburg, *Patent Carrots and Sticks: A Model of Nonobviousness*, 12 LEWIS & CLARK L. REV. 547, 548–49, 573 (2008).

22. *See, e.g.*, Oren Bar-Gill & Gideon Parchomowsky, *A Marketplace for Ideas?*, 84 TEX. L. REV. 395, 398 (2005) (categorizing "the inventive process into three distinct stages: (i) conception; (ii) development; and (iii) commercialization"); E. Layton, *Conditions of Technological Development*, *in* SCIENCE, TECHNOLOGY AND SOCIETY 197, 198 (Ina Spiegel-Rösing & Derek de Solla Price eds., 1977) ("What is needed is an understanding of technology from inside, both as a body of knowledge and as a social system. Instead, technology is often treated as a 'black box' whose contents and behavior may be assumed to be common knowledge."); Ted Sichelman, *Commercializing Patents*, 62 STAN. L. REV. 341, 348–54 (2010) (describing a stylized model of invention as proceeding through five stages: identification of a problem, development of a prototype, market testing and marketing, distribution, and product improvement).

In Part I, I begin by justifying a socio-historical approach to patent law, showing how it is both consistent with and required by the *KSR* line of Supreme Court cases. I argue that this approach can give content to three related concerns that underlie the Court's decision in *KSR*: (1) concerns about differentiating inventions that would be delayed or neglected absent a patent incentive from those that would arise through routine research, (2) concerns about differentiating "predictable" from "unique" inventions, and (3) concerns about the detrimental effects of patents on follow-on innovators. I also show how current law and economics theories that interpret obviousness as encouraging patentees to pursue more economically risky or uncertain projects are incomplete because they fail to take into account the social dimension of risk taking and uncertainty.

Part II draws from sociological analyses of historical case studies of innovation to provide a richer understanding of the context of innovation. I focus on three types of social phenomena that affect the pace and content of innovation. First, rather than focus on individuals and their cognitive abilities as the drivers of innovation, a sociological view of innovation emphasizes the central role of communities of practice in which individual inventors are embedded. In a sociological model, discovery is relational, emerging from an iterative back-and-forth among researchers in different communities of practice. Such a focus allows us to view innovation as both stimulated and hindered by the interrelated processes of specialization and intellectual migration between communities of practice. Innovation often takes place through the intellectual migration of scientists or innovators from one discipline or community of practice to another; these scientists and innovators bring their research tools to bear onto questions in a different field and reframe existing questions using language and concepts from their own disciplines.

The flip side of this intellectual migration is the existence of persistent barriers between specialized communities of practice and their respective modes of thought. Specialization creates both cognitive and structural impediments to innovation. Specialization can erect structural barriers to innovation by fostering a set of vested interests in particular research tools, approaches, and questions. In turn, these vested interests generate resistance to new approaches from outside the specialty. That migration across different specialties is often difficult helps explain why some inventions, when viewed retrospectively, appear to have taken an unaccountably long time to develop given the then-available knowledge across specialties.

Second, I show how within each specialty or practice community, innovators routinely rely on interpersonal relationships of trust and authority to determine which research programs and methodologies are legitimate and interesting. What constitutes legitimate lines of research or credible experimental designs often depends on the opinion of a "core-set" of practitioners within the discipline. Opposition from such a core-set can create powerful social barriers to innovation.

Third, I examine the role of unexpected discoveries—a heuristic often used by courts as a marker for nonobviousness—on the pace and content of innovation. I argue for a more fine-grained analysis of historical cases, which reveals three distinct types of "unexpected inventions." Importantly, one of these subtypes—anomalous observations that are intrinsic to a particular research program—is likely to spark swift follow-on innovation, thus suggesting a context in which broad patent rights may impose particularly high social costs.

Part III applies the insights from Part II to the design of patent law. I focus on the impact of a socio-historical approach on obviousness theory and doctrine—a focus arising from the pivotal role of the obviousness inquiry on weeding out inventions undeserving of patent protection. I argue that a nuanced understanding of the social context of innovation counsels a reorientation of the current obviousness inquiry to focus on identifying and rewarding in order to incentivize those inventions that transport ideas, techniques, and problems across disciplinary or community-of-practice boundaries. In practice, this means that defining the relevant community of practice should take center stage in determinations of obviousness. The emphasis should be on whether a person having ordinary skill in the art (PHOSITA) as a member of a community of practice would have identified the problem addressed by the invention—especially in light of current problems considered legitimate and interesting by the relevant community, on whether she would have considered the specific references at issue, and on how much consideration she would have given each one of them.

To further operationalize this inquiry, I argue that both the Patent and Trademark Office (PTO) and courts should consider evidence demonstrating that the inventor used tools or insights from other disciplines or communities in coming up with the invention as additional indicia of nonobviousness. This prescription is subject to an important caveat that takes into account private responses to the specialization problem. Where interdisciplinary team approaches to problem solving are the norm, patent law may not need to play an important role in stimulating cross-disciplinarity. In this case, a team having ordinary skill in the art, rather than a person of ordinary skill in the art, would be the appropriate unit of analysis.

A socio-historical approach also leads to two refinements of the indicia of nonobviousness currently employed by both the PTO and courts. First, "skepticism" should be reformulated as "persistent skepticism from the relevant 'core-set' of experts in the field." Because skepticism is part and parcel of scientific research, evidence of skepticism alone is not a strong marker of nonobviousness. On the other hand, persistent skepticism from the core-set of experts in the field is a particularly important secondary consideration in high-uncertainty research areas, where judgments based on relationships of trust and authority are likely to be most prevalent. Second, the category of "unexpected results" as a marker of inventions that are likely to be unique is overbroad. This is because unexpected results that arise as anomalous observations directly resulting from a planned research program are likely to be discovered simultaneously by multiple research teams. In this case, the key question is *not* whether the results themselves were unexpected but rather whether patent law was needed to stimulate the particular line of research leading to the unexpected result (i.e., to stimulate a race for the patent).

By providing an understanding of innovation rooted in the institutional and group dynamics of scientific research, this Article joins a growing body of scholarship that seeks to complement law and economics approaches to innovation by presenting a more nuanced picture of how innovation actually takes place.[23] This body of scholarship, however, has focused primarily on the psychology of creativity and motivation—or what Bacon termed the "mental" constraints to innovation—neglecting to investigate its social aspects.[24]

23. *See, e.g.*, Jeanne C. Fromer, *A Psychology of Intellectual Property*, 104 NW. U. L. REV. 1441 (2010) (arguing that—to better foster the creative process—research on the psychology of creativity should inform the design of patent and copyright law); Gregory N. Mandel, *To Promote the Creative Process: Intellectual Property Law and the Psychology of Creativity*, 86 NOTRE DAME L. REV. 1999 (2011) (same); Jessica Silbey, *The Mythical Beginnings of Intellectual Property*, 15 GEO. MASON L. REV. 319 (2008) (arguing that narrative theory can provide a novel explanation for the current structure and content of intellectual property law).

24. There are important exceptions to this psychological focus in recent patent law work. One example is the interdisciplinary work on intellectual property sponsored by the Society for Critical Exchange through the workshop "Con/texts of Invention" and culminating in the collection of essays, MAKING AND UNMAKING INTELLECTUAL PROPERTY: CREATIVE PRODUCTION IN LEGAL AND CULTURAL PERSPECTIVE (Mario Biagioli et al. eds., 2011) (The program for the working conference can be found at *Con/texts of Invention: A Working Conference of the Society for Critical Exchange*, THE SOC'Y FOR CRITICAL EXCH., http://www.cwru.edu/affil/sce/Contexts_of_Invention.html (last visited Mar. 15, 2013)). *See, e.g.*, Fiona Murray, *Patenting Life: How the Oncomouse Patent Changed the Lives of Mice and Men*, *in* MAKING AND UNMAKING INTELLECTUAL PROPERTY, *supra*, at 399, 406–07 (analyzing the impact of patent law on the social norms of cancer researchers as a community of practice). The literature on user innovation also employs a sociological approach to understanding the origin of innovation as the highly collaborative (and thus inherently relational) effort of multiple users embedded in distinct communities of practice. *See, e.g.*, ERIC VON HIPPEL, DEMOCRATIZING INNOVATION 93–97 (2005) (describing the formation of specialized user

I. THE NEED FOR A SOCIO-HISTORICAL APPROACH

In this Part, I analyze obviousness jurisprudence as an entry point to examine how a socio-historical approach to patent law is grounded in the Supreme Court's renewed emphasis on the context of invention. Although an approach to patent law based on insights from science and technology studies has implications for patent law more broadly, an initial focus on the obviousness doctrine is warranted given its key role as "the final gatekeeper of the patent system."[25]

I first provide a brief background of the Court's *KSR* decision, which set the stage for a renewed focus on "real world" innovators. I identify three key motivations behind the Court's move to a more realistic model of invention: (1) concerns about identifying inventions that would be delayed or neglected absent a patent incentive (i.e., invention timing issues); (2) concerns about identifying inventions that are more likely to be unique, and not independently invented in the course of routine research; and (3) concerns about granting patents to inventions that may have the net effect of stifling innovation. Identifying likely delayed or unique inventions, as well as those that are likely to impose a net cost on innovation, I argue, requires a nuanced understanding of the context of innovation that can only be provided by a historical and sociological analysis. Finally, I end this Part with an analysis of law and economics approaches to the obviousness doctrine, comparing these approaches to a socio-historical approach.

A. Supreme Court Doctrine from Graham *to* KSR

The Supreme Court's *KSR* decision has been hailed as "the most significant patent case in at least a quarter century," as it upended the Federal Circuit's obviousness jurisprudence—a doctrine long considered the gatekeeper of the patent bargain between inventors and society.[26] By replacing the Federal Circuit's TSM test with a flexible standard, the Court refocused the obviousness inquiry on how a real-life PHOSITA, possessing both "creativity" and "common sense," is likely to act.[27]

The judicially created TSM test emerged from a concern that assessments of obviousness, in particular in cases involving the

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"innovation communities" which often provide "sociability, support, information, a sense of belonging, and social identity" to their members).

25. MERGES & DUFFY, *supra* note 15, at 620.

26. John F. Duffy, KSR v. Teleflex*: Predictable Reform of Patent Substance and Procedure in the Judiciary*, 106 MICH. L. REV. FIRST IMPRESSIONS 34, 34 (2007), http://www.michiganlawreview.org/assets/fi/106/duffy.pdf.

27. *KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398, 421 (2007).

combination of known elements from the prior art, would be subject to hindsight bias.[28] That is, when faced with the *fait accompli* of an invention and several hand-picked references that, in combination, amounted to the invention, common sense may indicate that combining those references would be a routine task falling below the threshold of patentability.[29] To correct for this hindsight bias, the TSM test required that the prior art references include some teaching, suggestion, or motivation to combine those references.[30]

The TSM test had been sharply criticized as diverging from binding Supreme Court precedent by setting too low a standard of patentability—especially when applied to require a showing of an *explicit* teaching, suggestion, or motivation to combine references.[31] In 1966—forty-one years before the *KSR* decision—the Supreme Court, in *Graham v. John Deere Co.*[32] and a series of companion cases, set forth what it termed a "functional approach to questions of patentability"[33] that required a case-by-case comparison of "the scope and content of the prior art," "differences between the prior art and the claims at issue," and "the level of ordinary skill in the pertinent art."[34] Importantly, the Court in *Graham* emphasized that the "*circumstances surrounding the origin* of the subject matter sought to be patented" are relevant to the obviousness inquiry.[35] Although the Court did not expand on how the invention story should inform patentability, it listed three factors—"commercial success, long felt but unsolved needs, [and] failure of others"—that could serve as

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28. *See, e.g.*, *In re Dembiczak*, 175 F.3d 994, 999 (Fed. Cir. 1999); *In re Rouffet*, 149 F.3d 1350, 1357–59 (Fed. Cir. 1998).

29. *See, e.g.*, Mandel, *supra* note 17, at 1426–28; Gregory Mandel, *Patently Non-obvious II: Experimental Study on the Hindsight Issue before the Supreme Court in* KSR v. Teleflex, 9 YALE J.L. & TECH. 1 (2007), http://yjolt.org/volume_9.

30. *See, e.g.*, *In re Lee*, 277 F.3d 1338, 1342–44 (Fed. Cir. 2002) ("The 'common knowledge and common sense' on which the Board relied in rejecting Lee's application are not the specialized knowledge and expertise contemplated by the Administrative Procedure Act."). When the Supreme Court decided *KSR*, some Federal Circuit opinions held that the motivation to combine references could be implicit in the available knowledge and tools of the art, thus bringing the TSM test more in line with the Court's decision in *KSR*. *See, e.g.*, *Rouffet*, 149 F.3d at 1355.

31. *See, e.g.*, Brief of Intellectual Property Law Professors as Amici Curiae in Support of Petitioner at 23–26, *KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398 (2006) (No. 04-1350), 2006 WL 2452369 at 14–15; R. Polk Wagner & Katherine J. Strandburg, Debate, *The Obviousness Requirement in the Patent Law*, 155 U. PA. L. REV. PENNUMBRA 96, 101 (2006), http://www.pennumbra.com/debates/debate.php?did=2.

32. 383 U.S. 1 (1966).

33. *Id.* at 12.

34. *Id.* at 17.

35. *Id.* at 17–18 (emphasis added).

"secondary considerations" of nonobviousness.[36] Given the *Graham* Court's concern with "develop[ing] some means of weeding out those inventions which would not be disclosed or devised but for the inducement of a patent,"[37] these secondary considerations act as heuristics to identify classes of inventions that are likely patent-induced.

Critics of the Federal Circuit's obviousness jurisprudence charged that, in its concern to prevent hindsight bias and ensure uniformity, the Federal Circuit's rigid ruling had strayed from the expansive approach embraced by the Court in *Graham*. The Court in *KSR* agreed. The TSM test required little focus on the actual skills of a person having ordinary skill in the art, privileging instead the role of patent examiners and courts in identifying written documents that would contain hints to teach, suggest, or motivate the combination of elements present in the invention.[38] The Court's rejection of the TSM test brought the focus of the inquiry back to the perspective of a person of skill in the art—imagined as a real-world, creative individual.[39] According to the Court, such a person is not an "automaton," who relies only on the teachings of printed references, but rather an individual with imagination and a stock of background knowledge.[40]

In bringing the obviousness inquiry back to how a "real life" PHOSITA would attempt to solve existing problems in the art, the Court in *KSR* implicitly embraced a socio-historical approach to innovation.[41]

36. *Id.* The Court indicated that this list of factors was noninclusive by adding "etc." *Id.* at 17. Indeed, the Federal Circuit has expanded on the list of secondary considerations (or "objective indicia") that can complement the obviousness inquiry to include skepticism, teaching away, and unexpected results, among others. *See Monarch Knitting Mach. Corp. v. Sulzer Morat GMBH*, 139 F.3d 877, 883–86 (Fed. Cir. 1998); *Gillette Co. v. S.C. Johnson & Son, Inc.*, 919 F.2d 720, 725 (Fed. Cir. 1990).

37. *Graham*, 383 U.S. at 11.

38. *See, e.g.*, Rebecca S. Eisenberg, *Obvious to Whom? Evaluating Inventions from the Perspective of PHOSITA*, 19 BERKELEY TECH. L.J. 885, 889 (2004); Wagner & Strandburg, *supra* note 31, at 101 ("Beyond reciting a PHOSITA 'resume,' . . . discussion about what problems a PHOSITA solves, what tools she ordinarily applies, or what kinds of experiments she routinely performs is virtually absent from Federal Circuit opinions.").

39. *See KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398, 415 (2007); *see also* Durie & Lemley, *supra* note 10, at 999 ("[T]he one consistent strand that runs through the opinion is a rejection of rigid rules, replaced with a case-by-case focus on what actual scientists in the field would know or could develop with ordinary inventive skill.").

40. *KSR*, 550 U.S. at 421 ("A person of ordinary skill is also a person of ordinary creativity, not an automaton.").

41. *See* Meurer & Strandburg, *supra* note 21, at 572. Michael Meurer and Katherine Strandburg argue that *KSR* "endorses the contextual view of nonobviousness" that requires taking into account the "social and economic context" of the invention. *Id.* They do not, however, analyze the content of this "social context." Their view of contextual factors appears limited to technological advances, as well as regulatory and

That is, if the goal of the obviousness inquiry is to identify those inventions that would likely require the inducement of a patent,[42] and if the TSM test can no longer be used as a proxy to do so, the Court's "real-world" approach compels an analysis of how real-world inventions are developed. This includes understanding those factors intrinsic to how scientific research and innovation more broadly are done that affect which research projects are undertaken and which are not, and that explain why some innovations, when viewed in retrospect, took a long time to develop given the then-existing knowledge in the art. It also includes an appreciation of those circumstances in which innovation is likely to take place at a rapid pace. Indeed, following *KSR*, the Federal Circuit has begun to place more weight on "secondary considerations" in the obviousness inquiry, increasingly referring to these factors as "objective considerations" that must be taken into account in any determination of nonobviousness.[43] The Court's *KSR* decision can be interpreted as motivated by three related concerns, each one of them aimed at operationalizing the obviousness inquiry—to identify those inventions that would not come about (or would be significantly delayed) absent patent protection.[44]

1. CONCERNS REGARDING INVENTION TIMING

First, the Court was concerned with differentiating inventions that would be delayed or neglected absent a patent incentive from those that would arise under routine research. The Court distinguished "advances

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economic changes surrounding the invention. *Id.* Nevertheless, their interpretation of the *KSR* decision as requiring a contextual inquiry is congruent with my view of *KSR* as requiring an understanding of the social determinants of innovation.

42. I include here those inventions for which patents act as an accelerant.

43. *See, e.g.*, *In re Cyclobenzaprine Hydrochloride Extended-Release Capsule Patent Litig.*, 676 F.3d 1063, 1075 (Fed. Cir. 2012) (describing considerations of nonobviousness such as "the failure of others to make the patented invention; longfelt but unsolved needs fulfilled by the patented invention; commercial success of the patented invention; . . . and unexpected results produced by the patented invention" as "objective" and reversing the District Court's determination of obviousness for failing to take these considerations into account).

44. Although the Court in *KSR* does not explicitly articulate a concern with inventive delay, understanding the obviousness standard as accelerating innovation is consistent with the Court's emphasis on "skepticism" and "teaching away" as markers of nonobviousness, as well as with law and economics literature on patent law that ties patent protection to the *acceleration* of innovation. *See, e.g.*, U.S. FED. TRADE COMM'N, TO PROMOTE INNOVATION: THE PROPER BALANCE OF COMPETITION AND PATENT LAW AND POLICY ch. 1 at 37 (2003), *available at* www.ftc.gov/os/2003/10/innovationrpt.pdf (defining "unwarranted patents" as those given for "inventions that would have emerged *in roughly the same time frame*" even absent patent protection (emphasis added)).

that would occur in the ordinary course [of research]" (or "ordinary innovation") from "real innovation."[45] Although the Court is unclear on what it means by "ordinary course" (and scientists would be hard-pressed to distinguish instances in which they are really innovating from those in which they are conducting routine research) it makes sense to interpret this category as defining the "competitive baseline,"[46] that is, those combinations of prior art elements that would arise from market and other competitive forces. Indeed, the Court in *KSR* explicitly noted that "design incentives and other market forces" can drive combinations and variations of existing prior art elements.[47] Because these combinations would be expected to emerge naturally from market competition, a patent is unnecessary to stimulate their invention; thus, they are obvious and unpatentable.

While identifying the competitive baseline can prove particularly elusive,[48] a socio-historical perspective can help identify inventions likely to be at the other side of the ledger: delayed or neglected absent patent protection. The Court in *KSR* discussed *United States v. Adams*,[49] a case decided after *Graham* that illustrates a specific instance in which the prior art "taught away" from the invention (i.e., thought it not feasible) and experts were skeptical that the invention would work.[50] By rewarding with a patent those inventors who take the risk to pursue a combination of elements that experts find ill-advised, patent law nudges the timing of that particular invention to an earlier date. A socio-historical approach can not only provide data to support or discourage the use of specific secondary considerations as markers for invention delay or neglect, but also point to relevant new secondary considerations.

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45. *KSR*, 550 U.S. at 419; *see also id.* at 421 (differentiating "the product . . . of innovation" from that of "ordinary skill and common sense"); *id.* at 427 (remarking that "the results of ordinary innovation are not the subject of exclusive rights under the patent laws").

46. *See* Wagner & Strandburg, *supra* note 31, at 103.

47. *KSR*, 550 U.S. at 417.

48. *See, e.g.*, U.S. FED. TRADE COMM'N, *supra* note 44, at ch. 1 at 11 (noting that most patent law experts and business leaders agree that the "but for" obviousness standard—requiring to deny patents to those inventions which do not require patent protection to emerge—"cannot practically be applied in individual cases"). *But see* Abramowicz & Duffy, *supra* note 10, at 1614 (describing the obviousness standard as "establish[ing] a baseline that is independent of the patent system because it looks to the economic forces that would exist without patents," and seeking to operationalize it).

49. 383 U.S. 39 (1966).

50. *Id.* at 51–52; *KSR*, 550 U.S. at 416.

2. CONCERNS REGARDING UNIQUE INVENTIONS

The Court's concern with differentiating "predictable" from "unpredictable" or "unexpected" discoveries, reflected in multiple passages in the opinion, can also be interpreted as an attempt to identify and reward those inventions that are more likely to be unique—and thus less likely to be made independently and near-simultaneously by multiple inventors in the course of their research.[51] According to the Court, predictable improvements are obvious because multiple inventors would be able to appreciate the outcome of a particular predictable combination (and thus likely to try that combination) even before investing in costly and risky preliminary research to determine the viability of a research program.[52] The Court notes that predictable advances would be made in the course of "ordinary" innovation and thus, under the interpretation advanced previously, are likely sufficiently stimulated by baseline competition.[53]

Determining whether an invention is predictable, however, requires answering: predictable to whom?[54] As I argue in Parts II and III, getting the answer to this question right requires an understanding of the dynamics of specialization, teamwork, and the intellectual migration of scientists/innovators and ideas across specialties.

3. CONCERNS REGARDING FOLLOW-ON INNOVATION

Patents can have a net negative effect on innovation if they are likely to stifle follow-on research. This can happen, for example, if a particular field is crowded with a thicket of patents on "minor" or "routine" improvements, or if fuzzy patent boundaries make it difficult to distinguish between infringing and noninfringing behavior.[55] In refusing

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51. *See, e.g.*, *KSR*, 550 U.S. at 416 ("The combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results."); *id.* at 417 ("If a person of ordinary skill can implement a predictable variation, § 103 likely bars its patentability. . . . [A] court must ask whether the improvement is more than the predictable use of prior art elements according to their established functions.").

52. *Id.* at 416 ("The combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results.").

53. *Id.* at 417.

54. *See, e.g.*, Eisenberg, *supra* note 38.

55. *See, e.g.*, JAMES BESSEN & MICHAEL J. MEURER, PATENT FAILURE (2008) (arguing that poor patent notice of patent claim boundaries has resulted in an inefficient patent system that imposes a net cost on innovators in most industries); Michael A. Heller & Rebecca S. Eisenberg, *Can Patents Deter Innovation? The Anticommons in Biomedical Research*, 280 SCIENCE 698, 700 (1998) (arguing that patent thickets in the

to grant patents for "routine research," the Court in *KSR* emphasized the detrimental effect that these patents could have on subsequent inventors: "[A]s progress beginning from higher levels of achievement is expected in the normal course, the results of ordinary innovation are not the subject of exclusive rights under the patent laws. Were it otherwise patents might stifle, rather than promote, the progress of useful arts."[56]

The Court assumed that the converse of predictable inventions ("unpredictable" or "unexpected" results) served as a signpost for those unique inventions, unlikely to be identified in the ordinary course of research and less likely to have a net negative cost on innovation.[57] Predictable findings, however, are only a subset of inventions that are likely to be made near-simultaneously. Indeed, historically, many initially unpredictable findings were discovered independently by multiple research teams.[58]

Patent law literature has recognized and grappled with the problem that independent, near-simultaneous invention presents for patent law. As Mark Lemley remarks in a recent article, when an invention is likely to be developed independently and near-simultaneously by multiple researchers, granting a patent to the first inventor appears to act simply to withdraw from the public domain knowledge that would have otherwise been publicly available without the grant of a patent to the first inventor.[59] Lemley argues that patent races can partially justify granting patents to the first inventor, because patent races may themselves encourage or set in motion those independent research programs leading to near-simultaneous invention—i.e., races encourage competition for a patent prize.[60] Others have advocated granting a patent to the first inventor, but allowing subsequent inventors to invoke an independent

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biomedical sciences can lead to patent owners blocking each other, as well as the development of useful products); Katherine Strandburg, *What Does the Public Get? Experimental Use and the Patent Bargain*, 2004 WIS. L. REV. 81.

56. *KSR*, 550 U.S. at 427.

57. *See, e.g.*, *id.* at 416 ("The fact that the elements worked together in an unexpected and fruitful manner supported the conclusion that Adams' design was not obvious to those skilled in the art.").

58. *See, e.g.*, Mark A. Lemley, *The Myth of the Sole Inventor*, 110 MICH. L. REV. 709, 712–33 (2012) (giving historical examples of near-simultaneous inventions).

59. *Id.* at 737.

60. *Id.* at 754 ("[I]t is at least possible that, but for the spur of competition, none of the racing parties would ever have gotten to the invention."); Duffy, *supra* note 9, at 446 (arguing that patent races accelerate the dedication of the invention to the public); *see also* Abramowicz & Duffy, *supra* note 10, at 1677 (noting that the existence of near-simultaneous invention could simply indicate the existence of a patent race, but arguing that evidence that an invention was invented independently by a party who was not motivated by a patent should count as strong evidence of obviousness).

inventor defense to infringement.[61] Another proposal to address the problem of simultaneous invention seeks to bring the patent system closer to the copyright system by limiting infringement to actual copying.[62]

A socio-historical account of innovation does not settle the debate on how we should deal with near-simultaneous invention. But, as I argue in Parts II and III, it can point to the types of unexpected results that are likely to be identified simultaneously or nearly simultaneously by several groups of inventors (those that contradict widely held expectations but arise in the course of research programs pursued in parallel by multiple individuals or teams) and to those that are more likely to be unique (those that arise serendipitously and are unrelated to the research program under investigation). It also demonstrates how relying on the broad label "unexpected results" as a proxy for identifying inventions above the competitive baseline is problematic, as it hides different underlying dynamics of innovation.

B. Economic Theories on the Obviousness Standard

This Section examines the three dominant economic theories that seek to justify and give content to the obviousness standard. For each theory, I highlight how a socio-historical approach complements each perspective. The approach is developed in depth in Parts II and III.

1. OBVIOUSNESS STANDARD AS ENCOURAGING RISKY PROJECTS

One economic justification for private rights in the products of innovation, advanced by Kenneth Arrow, conceptualizes innovation as the production of knowledge or information.[63] The production of information is inherently uncertain, and therefore risky, because its precise content can never be fully known in advance.[64] Given the uncertain nature of knowledge-producing activities, and absent patent

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61. *See, e.g.*, Samson Vermont, *Independent Invention as a Defense to Patent Infringement*, 105 MICH. L. REV. 475 (2006); Carl Shapiro, *Prior User Rights*, 96 AM. ECON. REV. 92, 95 (2006); Stephen M. Maurer & Suzanne Scotchmer, *The Independent Invention Defence in Intellectual Property*, 69 ECONOMICA 535 (2002).

62. *See* Oskar Liivak, *Rethinking the Concept of Exclusion in Patent Law*, 98 GEO. L.J. 1643, 1647 (2010).

63. Kenneth J. Arrow, *Economic Welfare and the Allocation of Resources for Invention*, *in* THE RATE AND DIRECTION OF INVENTIVE ACTIVITY: ECONOMIC AND SOCIAL FACTORS 609, 616 (1962) ("The central economic fact about the processes of invention and research is that they are devoted to the production of information.").

64. *Id.*

rights, inventors will underinvest in information goods from a welfare economics point of view. Patents are a device to mitigate the risks inherent in the production of knowledge by rewarding successful investors with the right to exclude others from making, using, or selling their inventions.

Arrow classified all knowledge making as inherently risky, and thus provided a general justification for granting intellectual property to knowledge goods. But Arrow's conceptualization of patent rights as mitigating underinvestment in risky projects can justify the obviousness doctrine as fostering investment in such projects and provide a test for differentiating patentable from unpatentable inventions. Thus, in this model, the obviousness test can be conceptualized as preventing the patenting of inventions that are not risky to undertake, and whose outcome is sufficiently known (or "predictable") in advance.[65] Robert Merges has developed Arrow's analysis of research as overcoming uncertainty to propose an uncertainty-based economic model of obviousness. In this model, the obviousness standard would "reward[] one who successfully invents when the uncertainty facing her prior to the invention makes it more likely than not that the invention won't succeed."[66]

A related interpretation of risk, advanced by William Landes, Richard Posner, and Robert Merges, ties uncertainty to cost.[67] When creating knowledge, and thus dispelling uncertainty, is costly, firms will tend to wait for competitors to make the initial investment and then copy the final product. As a consequence, all firms will underinvest in knowledge goods absent patent protection.[68] Patents allow innovators to recoup the cost of their successive failures en route to the invention, thus encouraging the initial investment in risky projects. In this view, the obviousness doctrine prevents the patenting of low-hanging fruit: those inventions that are not costly to discover and develop because of a low likelihood of failure.

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65. *See* Merges, *supra* note 21, at 2 ("The nonobviousness standard encourages researchers to pursue projects whose success appears highly uncertain at the outset. The standard insists that only the results from uncertain research should be rewarded with a patent.").

66. *Id.* at 19 (emphasis omitted).

67. LANDES & POSNER, *supra* note 21, at 304–05; Merges, *supra* note 21, at 43 (arguing that high project costs are a good indication of high risk).

68. This justification for intellectual property protection is intimately related to the classical conceptualization of intellectual property goods as public goods that are nonrival and nonexcludable. *See* DONALD S. CHISUM ET AL., PRINCIPLES OF PATENT LAW 58–59 (1998).

But "risk" also has a social dimension. If obviousness is a "legal rule that influences behavior,"[69] nudging innovators to focus on those high-risk projects they may not otherwise undertake, designing such a rule must take into account pre-existing social constraints that influence the direction and pace of innovation. Thus, a fully developed theory of obviousness as rewarding risk taking should incorporate this social dimension.

2. OBVIOUSNESS STANDARD AS INFLUENCING CHOICE AMONG VARIOUS RESEARCH PROJECTS

A second economic model of obviousness, put forth by Michael Meurer and Katherine Strandburg, also understands the obviousness standard as rewarding uncertain, high-cost projects.[70] But they conceptualize obviousness as influencing the choice among a variety of possible research paths or projects to address a particular problem in the art, rather than as an "on/off" choice regarding whether to invest or not in pursuing a single research path towards an invention.[71] In this model, the right question is not whether an inventor will invest or not in addressing a particular problem, but rather, which one of the several possible research paths or approaches she will undertake. In this context, the obviousness standard can "prod an inventive entity to choose a more difficult research project" than would be privately optimal absent an obviousness threshold to patentability.[72] In turn, more difficult research projects are expected to yield a higher social benefit.[73]

Meurer and Strandburg recognize that identifying those socially beneficial projects that can be nudged by the obviousness standard requires "an understanding not only of the technology at issue, but also of the *social and economic context* in which it and similar technology is

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69. Merges, *supra* note 21, at 2.

70. Meurer & Strandburg, *supra* note 41, at 557.

71. *Id.* at 556.

72. *Id.* at 561.

73. Meurer and Strandburg plausibly assume that a higher degree of difficulty will yield more socially beneficial projects because (1) firms are likely to weed out those likely valueless yet difficult projects and (2) more difficult projects are likely to "lead to more extensive and broader opportunities for follow-on innovation." *Id.* at 552–53, 561. In Meurer and Strandburg's model, the obviousness standard can serve as a lever to influence innovators to choose more difficult, and thus more socially beneficial, projects only insofar as the expected private benefits of pursuing a nonpatentable, lower-tech research project are at least equal to the benefits of pursuing a patentable, higher-tech project. *Id.* at 550. In other words, the standard is constrained in its ability to influence risk-taking by the expected returns of lower-risk, unpatentable projects. *Id.* at 560–64.

developed."[74] Indeed, they urge courts to consider "*everything* . . . that affects the *ex ante* expected costs and benefits to inventors and thus affects their likely choices of research direction."[75] Although the contextual factors these authors list appear limited to economic and technological changes surrounding the invention, these changes alone cannot fully account for whether a particular research path will be undertaken. Rather, a more detailed account of social constraints to innovation is needed to provide a full picture of the costs and benefits of pursuing particular research paths.[76]

3. OBVIOUSNESS STANDARD AS INSTANTIATING AN ECONOMIC INDUCEMENT STANDARD

In a recent paper, Michael Abramowicz and John Duffy seek to operationalize the inducement standard first articulated by the Court in *Graham*: that patents should be awarded only to "those inventions which would not be disclosed or devised but for the inducement of a patent."[77] This standard was widely understood as aspirationally correct in trying to weed out inventions that would have arisen from market competition—the competitive baseline—from those that require patents to come about or be disclosed, but as hard or impossible to apply directly.[78] Their reformulation of the standard contains three important refinements. First, they incorporate the element of time, thus seeking to identify not only those inventions that would *never* have been disclosed or devised but for a patent incentive (as the *Graham* standard can be plainly read to require), but those which "would not have [been] disclosed or devised for

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74. *Id.* at 572 (emphasis added). The authors list three contextual factors as relevant to a determination of whether an invention should be deemed obvious and thus denied patent protection: the existence of (1) "collateral technological advances"; (2) "regulatory changes"; or (3) "shifts in demand" that alter the private costs and/or benefits of pursuing a particular research path. *Id.*

75. *Id.* at 573 (emphasis added).

76. *See, e.g.*, Joan H. Fujimura, *Constructing 'Do-able' Problems in Cancer Research: Articulating Alignment*, 17 SOC. STUD. SCI. 257 (1987) (arguing that "technology alone cannot make problems doable" in science and outlining a series of social conditions that either constrain or facilitate the construction of doable problems, defined as problems for which a research program or programs can be developed and pursued); *see also* Parts II, III.

77. Abramowicz & Duffy, *supra* note 10, at 1590 (quoting *Graham v. John Deere Co.*, 383 U.S. 1, 11 (1965)).

78. *See, e.g.*, Robert P. Merges, *Uncertainty and the Standard of Patentability*, 7 HIGH TECH. L.J. 1, 19 (1992) (noting that "[i]t would be impossible in most cases to apply this standard").

a substantial period of time" as deserving of patent protection.[79] This point is in agreement with the interpretation of *KSR* I advance above as concerned with the *timing* of invention and recognizes that an important goal of the patent system is to accelerate innovation.[80] Second, it moves away from defining a PHOSITA cognitively (i.e., by reference to what a PHOSITA is likely to know or understand) to embracing an economic definition of nonobviousness that focuses on whether, in the absence of patents, a person or entity would "find it economically obvious to undertake the research necessary for success."[81] This definition incorporates concerns about uncertainty and cost. A highly uncertain and/or costly innovation would likely *not* be economically obvious absent patent protection.[82] Third, it seeks to provide courts tools to identify the competitive baseline by identifying specific economic contexts that are likely to facilitate invention without patent protection.[83]

This economic approach is largely compatible with a socio-historical approach. However, rather than focus on the *economic* baseline that facilitates innovation, the latter focuses on the *structural and social factors* that both facilitate and hinder it. Sociologists and historians of science have long focused on the *timing* of inventions, researching factors that both accelerate and constrain innovation, including those that influence decisions to initiate or halt research and those that impact the diffusion of innovative ideas or techniques. Thus, while Abramowicz and Duffy focus specifically on "establish[ing] a baseline that is independent of the patent system because it looks to the economic forces that would exist without patents,"[84] my analysis looks to structural, sociological forces that define what may be called a "social baseline" of innovation. Both perspectives are necessary to fully describe the background forces that influence the timing of innovation. Also important, but not directly addressed in Abramowicz and Duffy's analysis, is the identification of factors that are likely to delay or obstruct innovation as points in which patent law can serve as a lever to encourage investment. The next Part of this Article sets out to explore in detail the content of these structural determinants of innovation.

79. Abramowicz & Duffy, *supra* note 10, at 1599.

80. *See supra* Part I.A.1.

81. Abramowicz & Duffy, *supra* note 10, at 1655.

82. *Id.* at 1663 ("[W]hether an invention is obvious depends on how costly an experiment would be and the probability that the experiment would be successful.").

83. The authors identify two circumstances—"a positive demand shock shortly before the invention" and "a rapidly declining cost of invention"—as proxies showing that a patent is unnecessary to induce a particular innovation. *Id.* at 1656.

84. *Id.* at 1614.

II. CREATION AND DIFFUSION OF SCIENTIFIC AND TECHNICAL KNOWLEDGE: INSIGHTS FROM HISTORY AND SOCIOLOGY OF SCIENCE AND TECHNOLOGY

The study of science from a sociological perspective dates back to the 1930s when Robert Merton and Bernard Barber began to analyze the reward system of academic science and its social norms.[85] In contrast to a historical approach—which until then tended to focus on the biographical details of those considered key scientific figures and thus on the *cognitive* context of scientific innovation[86]—the sociological approach pioneered by Merton and Barber sought to study academic science as a social institution that constrained in specific and describable ways the behavior of scientists. Merton famously proposed a set of norms as forming the *ethos* of the academic scientific community, an ideal pattern of behavior that all scientists strived to follow. The Mertonian norms of communalism, universalism, disinterestedness, originality, and skepticism,[87] have generated an enormous amount of research into how well this ethos is internalized by scientists, how well it is enforced, and how it is modified by the encroachment of commercial interests into academia.[88]

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85. *See* ROBERT K. MERTON, THE SOCIOLOGY OF SCIENCE: THEORETICAL AND EMPIRICAL INVESTIGATIONS (Norman W. Storer ed., 1973); NORMAN W. STORER, THE SOCIAL SYSTEM OF SCIENCE 86–90 (1966); THE SOCIOLOGY OF SCIENCE (Bernard Barber & Walter Hirsch eds., 1962); Joseph Ben-David & Teresa A. Sullivan, *Sociology of Science*, 1 ANN. REV. SOC. 203 (1975).

86. *See, e.g.*, JOHN ZIMAN, AN INTRODUCTION TO SCIENCE STUDIES: THE PHILOSOPHICAL AND SOCIAL ASPECTS OF SCIENCE AND TECHNOLOGY 92–93 (1984). John Ziman notes that traditional histories of science focused on "the *cognitive* context within which research was undertaken and discoveries made," attributing advances in scientific knowledge to "the discoveries and insights of particular individuals, each building upon the work of his or her predecessors." *Id.* at 92. In this context, "[t]he sources of scientific change are sought in the psychology of personal creativity, expressed in each instance within the context of the scientific knowledge available to the particular researcher." *Id.* The courts' description of a PHOSITA reflects much of this cognitive conception of discovery. It is this cognitive approach that Abramowicz and Duffy criticize in their recent article. Abramowicz & Duffy, *supra* note 10, at 1603–08; *see also infra* Part III.B.

87. MERTON, *supra* note 85, at 268–78 (defining the four sets of institutional imperatives as universalism, communism, disinterestedness, and organized skepticism); ZIMAN, *supra* note 86, at 84–86 (definiting the Mertonian norms as communalism, universalism, disinterestedness, originality, and skepticism). The Mertonian norms can briefly be described as follows: "Communalism: *Science is public knowledge, freely available to all*. . . . Universalism: *There are no privileged sources of scientific knowledge*. . . . Disinterestedness: *Science is done for its own sake*. Originality: *Science is the discovery of the unknown*. . . . Skepticism: *Scientists take nothing on trust*." ZIMAN, *supra* note 86, at 84–86.

88. Several legal scholars have explored how the availability of patents on the products of academic research impacts the Mertonian norms of academic science. *See,*

Merton's and Barber's efforts to describe the ethos of academic science took place in the backdrop of state-controlled Nazi and Stalinist science programs. Both scholars were concerned with showing that academic science could foster democracy and that, in turn, democracy was crucial to the practice of academic science.[89] Thus, Merton's original 1942 paper describing the norms of science emphasized the connection between free science and free society.[90] But their analysis took for granted the "content" of scientific knowledge itself.[91] In contrast, social studies of science, which emerged as a discipline in the 1960s, sought to show how scientific knowledge and technology itself is "influenced by the social and cultural contexts in which [it is] produced."[92] Social studies of science do not draw a sharp distinction between industrial and academic science or between "pure" and "applied" science. Rather, the development of technological innovation is understood as "regulated by just the same principles of scientific work as those that presided over the growth of the natural sciences themselves."[93]

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e.g., Rebecca S. Eisenberg, *Academic Freedom and Academic Values in Sponsored Research*, 66 TEX. L. REV. 1363, 1363 (1988) (discussing how university research sponsored by commercial interests could erode the "academic values" of disinterestedness and communalism by "directing the choice of research topics and restricting the publication of research results"); Rebecca S. Eisenberg, *Patents and the Progress of Science: Exclusive Rights and Experimental Use*, 56 U. CHI. L. REV. 1017, 1046 (1989) ("The idea of enforcing of exclusive rights in new discoveries against researchers fundamentally conflicts with traditional scientific norms . . . of 'communism' . . . ."); Arti K. Rai & Rebecca S. Eisenberg, *Bayh-Dole Reform and the Progress of Biomedicine*, 66 LAW & CONTEMP. PROBS. 289, 289 (2003) (discussing the impact of patenting on the research tradition of open science in which "longstanding norms call for relatively unfettered access to fundamental knowledge developed by prior researchers"); Arti Kaur Rai, *Regulating Scientific Research: Intellectual Property Rights and the Norms of Science*, 94 NW. U. L. REV. 77, 88–89 (1999) (exploring how the federal government's "concerted effort to apply property-based incentives to scientific research . . . changed significantly the traditional norms of scientific research," and citing Robert Merton, Bernard Barber, and Warren Hagstrom as prominent sociologists of science who have characterized the content of these norms).

89. *See, e.g.*, H.M. Collins, *The Sociology of Scientific Knowledge: Studies of Contemporary Science*, 9 ANN. REV. SOC. 265, 266 (emphasizing that "Merton's (1942) and Barber's (1952) thinking about the norms of science must be seen in the context of the rise of European totalitarianism"); David Edge, *Reinventing the Wheel*, *in* HANDBOOK OF SCIENCE AND TECHNOLOGY STUDIES 3, 10–11 (Sheila Jasanoff et al. eds., 1995).

90. *See* MERTON, *supra* note 85.

91. *See, e.g.*, MICHAEL MULKAY, SCIENCE AND THE SOCIOLOGY OF KNOWLEDGE 22 (1979) ("The whole tradition of sociological work on science . . . beginning with Merton's pioneering research in the 1930s and continuing off and on for thirty years or so, has systematically avoided examination of the substance of scientific thought.").

92. *See id.* at 1.

93. ZIMAN, *supra* note 86, at 130; *see also* STEVEN SHAPIN, THE SCIENTIFIC LIFE: A MORAL HISTORY OF A LATE MODERN VOCATION 2–3 (2008) (adopting the term

Social studies of science is an interdisciplinary field that uses sociological, anthropological, and historical methods to analyze how scientific knowledge and innovation is produced—or constrained—and disseminated.[94] Despite these varied methodological approaches, social studies of science and technology takes a decidedly empirical approach, emphasizing case studies of laboratories and other places where research is actually carried out. I take a social studies of science perspective grounded on historical case studies of innovation, or what I term a socio-historical approach. Three distinctive features of this approach, I argue, make its findings particularly relevant to the design of patent law. First, it focuses on the communal basis of scientific knowledge, paying particular attention to the influence of scientific specialization and scientific disciplines (or communities of innovation) on the pace and content of innovation.[95] More specifically, it emphasizes how specialization generates a set of vested social interests within the broader scientific community.[96] Second, it focuses on how the development of scientific knowledge and technology is intimately linked to relationships between science practitioners.[97] These relationships are built on trust and are influenced by authority.[98] Third, it pays attention to the contingent

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"technoscience" to avoid the categorization of innovations as either science or technology and arguing that the distinctions "between science and technology, between the institutions in which each was done, and between the motives and personal characteristics of the scientist and the technologist . . . have been greatly eroded *within* the worlds of science and technology and within the institutions where science and technology happen").

94. For an excellent overview of the field, see Steven Shapin, *Here and Everywhere: Sociology of Scientific Knowledge*, 21 ANN. REV. SOC. 289, 292 (1995).

95. *See, e.g.*, Joan H. Fujimura, *The Molecular Biological Bandwagon in Cancer Research: When Social Worlds Meet*, 35 SOC. PROBS. 261 (1988); Elihu M. Gerson, *Scientific Work and Social Worlds*, 4 KNOWLEDGE 357, 359 (1983); *see also* Sal Restivo, *The Theory Landscape in Science Studies*, *in* HANDBOOK OF SCIENCE AND TECHNOLOGY STUDIES, *supra* note 89, at 95, 107 (describing science as built through social relations and social practice, making "[t]he social group, not the individual, . . . the locus of knowledge"); Steven Shapin, *History of Science and Its Sociological Reconstructions*, 20 HIST. SCI. 157, 197 (1982) ("Knowledge is not regarded in this literature as contemplatively produced by isolated individuals; it is produced and judged to further particular *collectively sustained goals*." (emphasis added)).

96. *See, e.g.*, Restivo, *supra* note 95, at 106 (describing interest theory in science and technology studies); Shapin, *supra* note 95, at 164–65.

97. *See, e.g.*, STANLEY ARONOWITZ, SCIENCE AS POWER: DISCOURSE AND IDEOLOGY IN MODERN SOCIETY 30 (1988) (describing social studies of science as focusing on a "microsociology of knowledge in which the actual interactions of working scientists" take center stage).

98. *See, e.g.*, STEVEN SHAPIN, A SOCIAL HISTORY OF TRUTH: CIVILITY AND SCIENCE IN SEVENTEENTH-CENTURY ENGLAND (1994); STEVEN SHAPIN, NEVER PURE: HISTORICAL STUDIES OF SCIENCE AS IF IT WAS PRODUCED BY PEOPLE WITH BODIES,

circumstances affecting the production and evaluation of innovations, including the role of unexpected results in innovation. These three areas of inquiry correspond respectively to the next three Subsections of this Article.

A. Innovation Timing Studies

Understanding the rate of scientific change has been a central concern in the study of science from both historical and sociological perspectives. What is clear from these studies is that innovation does not depend solely on what scientific ideas happen to be current, or on the totality of available knowledge. Rather, innovation is discontinuous and nonlinear, "because it is involved in social relations that have their own logic."[99] This Section analyzes three social determinants to the rate of innovation: specialization, relationships of trust and authority, and unexpected discoveries.

1. SPECIALIZATION: COMMUNITIES OF PRACTICE, SOCIAL WORLDS, AND INVISIBLE COLLEGES

Rather than focus on the individual scientist or innovator and her cognitive abilities as the unit of analysis, a sociological approach to innovation focuses on the community of practice in which she is embedded. This sociological view of discovery criticizes canonical narratives that depict innovation as a psychological process, consisting of ideas or insights that emerge suddenly from the work of a single person. Because modern structures of scientific and technical knowledge are increasingly specialized,[100] no single researcher can master the content of an entire field, and "even the technical knowledge involved in the conduct of a single experiment in modern physics or biology is typically distributed across a range of specialist actors."[101] Thus, discovery is

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SITUATED IN TIME, SPACE, CULTURE, AND SOCIETY, AND STRUGGLING FOR CREDIBILITY AND AUTHORITY (2010).

99. Michel Callon, *Four Models for the Dynamics of Science*, *in* HANDBOOK OF SCIENCE AND TECHNOLOGY STUDIES, *supra* note 89, at 29, 49.

100. *See, e.g.*, Benjamin Jones, *As Science Evolves, How Can Science Policy?* (Nat'l Bureau of Econ. Research, Working Paper No. 16002, 2010), *available at* http://www.nber.org.ezproxy.library.wisc.edu/papers/w16002.pdf?new_window=1 (documenting how "ensuing generations of innovators spend longer in training and become more narrowly expert"); *see also* ZIMAN, *supra* note 86, at 74 ("Success against competition can only be achieved by extreme specialization. To gain and keep a place in the scientific community, it is practically essential to concentrate one's research on a very narrow range of problems in a very restricted field within a particular discipline.").

101. Shapin, supra note 94, at 302.

inherently relational, emerging from a complex, interactive back-and-forth among researchers, often in different communities of practice or social worlds.[102]

Sociologists and historians of science have used different approaches to defining the boundaries of these communities of practice, but all agree that they have more in common with networks of interaction than with sharply delineated geographic locales. That is, "communities of practice,"[103] "scientific social worlds,"[104] or "invisible colleges,"[105] as they have alternatively been called, are defined by a core set of activities: accepted practices, techniques, legitimate research goals, training procedures, and relationships among a cluster of practitioners.[106] In sociological terminology, the members of each community of practice share strong ties with each other, which are neither familial nor derived from a formal organizational structure, and which may be highly geographically dispersed.[107]

For example, a developmental biologist working with fruit flies as a model organism is likely to interact on a regular basis with other fly geneticists both to discuss substantive research questions and to share research tools. He will also interact, albeit less frequently, with scientists working on mouse or worm development, with embryologists, with researchers working on human diseases linked to developmental defects, and with computational biologists working on constructing development maps. He will be much less likely to interact with, for example, immunologists or biophysicists. The network of social interactions within a community of practice has its counterpart in the scientific

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102. *See, e.g.*, Elihu M. Gerson, *Premature Discovery Is Failure of Intersection among Social Worlds*, *in* PREMATURITY IN SCIENTIFIC DISCOVERY: ON RESISTANCE AND NEGLECT 280, 281 (Ernest B. Hook ed., 2002); Shapin, supra note 94, at 302 (remarking how "actors in different 'social worlds' are invariably involved in the making of scientific goods").

103. ETIENNE WENGER, COMMUNITIES OF PRACTICE: LEARNING, MEANING AND IDENTITY (1998).

104. "Social world" is a term in sociology first coined by Anselm Strauss in 1978 and refers to a set of "activities carried out in common with respect to a particular subject or area of concern." Gerson, *supra* note 95, at 359.

105. *See, e.g.*, DIANA CRANE, INVISIBLE COLLEGES: DIFFUSION OF KNOWLEDGE IN SCIENTIFIC COMMUNITIES (1972).

106. *See, e.g.*, Gerson, *supra* note 95, at 359; Michael Mulkay, *Conceptual Displacement and Migration in Science: A Prefatory Paper*, 4 SCI. STUD. 205, 229 (1974) ("[T]he various scientific disciplines, and to a lesser extent their component specialties, are comparatively distinct social units. Each discipline has its own language, techniques, legitimate research goals, training procedures, scientific societies and so on.").

107. *See, e.g.*, David Krackhardt, *The Strength of Strong Ties: The Importance of* Philos *in Organizations*, *in* NETWORKS AND ORGANIZATIONS: STRUCTURE, FORM, AND ACTION 216 (Nitin Nohria & Robert G. Eccles eds., 1992).

literature as a closely connected cluster of nodes in a citation network. Although these citation clusters are seldom sharply differentiated, "they are quite genuine groupings whose connections are usually mirrored in the social interactions of their members."[108]

Analyzing innovation from the perspective of communities of practice rather than individual researchers enables us to understand and describe many instances of innovation—and in particular breakthrough innovation—as processes at the intersection of one or more social worlds, catalyzed by intellectual migration and exchange among them. When scientists change communities of practice, "they take with them skills and concepts which they apply to the problems of their new field[s]."[109] Thus, innovation often takes place when tools and skills from one discipline are applied to another; when persistent problems are reframed in a new conceptual language and viewed from a different, more tractable angle; or when results are given different interpretations, which open up new avenues of inquiry.[110] This approach emphasizes the inadequacy of individualistic, purely cognitive views of innovation for interpreting how innovation—or any other form of knowledge creation—takes place.

Many historically significant discoveries can be conceptualized as coming about through intellectual migration from one community of practice to another. For example, the discovery of deoxyribonucleic acid (DNA) as the genetic material, which heralded the birth of molecular biology, is widely credited to the migration of a group of physicists to biology.[111] Max Delbrück—one of the key first "migrants" from physics to biology—describes the unique circumstances that enabled the cross-fertilization between theoretical physics and biology:

> [O]fficial seminars [in Nazi Germany] became dull. Many people emigrated, others did not leave but were not being

108. ZIMAN, *supra* note 86, at 75.

109. Mulkay, *supra* note 106, at 209.

110. The two most famous examples in the twentieth century of "reframing" a problem in the terms and concepts of another discipline are the reexpression of the concept of chemical bonding in terms of quantum mechanics and of the notion of a gene in terms of molecular biology. Gerson, *supra* note 95, at 364.

111. *See, e.g.*, JOSEPH ROUSE, KNOWLEDGE AND POWER: TOWARD A POLITICAL PHILOSOPHY OF SCIENCE 89 (1987) ("To grasp the potential of DNA as a research opportunity and act on it required the technical skills of X-ray crystallographers and structural organic chemists and a grasp of the significance of the possibilities for molecular studies of genetics that was most clearly displayed by the new group of geneticists (often physicists turned geneticists) working with bacteria and bacteriophages. . . . [T]here were very few places in the world where this configuration of skills and interests existed.").

> permitted to come to official seminars. We had a little private club which I had organized and which met once a week, mostly at my mother's house. First just theoretical physicists (I was at that time a theoretical physicist), and then theoretical physicists and biologists. The discussions we had at that time have had a remarkable long-range effect, an effect which astonished us all.[112]

The different way in which biologists, experimental physicists, and theoretical physicists approached the problem of genetic inheritance illustrates how interactions among communities of practice shape the pace and content of innovation. In the late 1920s, three scientists from Delbrück's informal private club—the geneticist Nikolay Timofeev-Ressovsky, the experimental physicist Karl Zimmer, and the theoretical physicist Delbrück himself—collaborated on experiments that applied X-rays to fruit flies in order to induce genetic mutations.[113] Timofeev viewed their experiments as part of his long-term aim to "develop a more speedy procedure for altering the genetic constitution of animals and plants in the service of man."[114] Zimmer, in contrast, was interested in understanding what physico-chemical changes were produced by ionizing radiation (X-rays).[115] On his part, Delbrück wanted to elucidate how physics could "account for two aspects of mutation—change and constancy."[116] To do so, he reframed the project and its conclusions in the language of quantum physics. Although this particular collaboration was one of several failed attempts on the road to the successful discovery of the structure of DNA, according to Zimmer, it "led to an entirely new line of thought: the application of concepts of quantum physics to biological problems."[117] Zimmer went on to add: "there is no doubt that in this way modern physical concepts came into contact with biology and that the synthesis of the specialties so initiated has been remarkably fruitful."[118] Thus, the serendipitous result of such "dull" official seminars was the bringing together of a group of scientists who would not normally have interacted with each other. Delbrück

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112. ROBERT OLBY, THE PATH TO THE DOUBLE HELIX 231 (1974) (quoting Max Delbrück, Chemistry and Society Lecture Series: *Homo Scientificus* According to Beckett (Feb. 24, 1971)).

113. *Id.* at 231–32.

114. *Id.* at 232.

115. *Id.*

116. *Id.* at 233.

117. *Id*. at 232.

118. *Id.*

facilitated the emergence of a new community of practice that had far-reaching implications for the development of modern biology.

The development of radio astronomy, which eventually led to the discovery of cosmic microwave background radiation and provided evidence for the Big Bang Theory, similarly grew out of the intersection of engineering, physics, and astronomy. Karl Jansky, an engineer at Bell Laboratories, first detected radio waves in outer space when studying the origin of static noise that interfered with transatlantic voice transmissions.[119] Astronomers had never seen any objects in the center of the galaxy because the dust clouds that surround it limited the effectiveness of the optical techniques widely used by astronomers.[120] Relatedly, the migration of physicists trained in radar techniques to astronomy greatly advanced astronomical meteor research which had until then been hindered by clouds and the emission of light from the sun and moon that interfered with optical measurements.[121]

The importance of intellectual migration for scientific innovation is not limited to breakthrough scientific advances comparable to those described above. Rather, intellectual migration can lead to innovation at a "micro" level. An example from my own experience as a Ph.D. researcher illustrates this point. I worked in the laboratory of Dr. Tian Xu, which in its early stages specialized in fruit fly development. The laboratory developed a technique to produce "clones" of cells—that is, a cluster of genetically identical cells arising from a single parent cell—in particular areas of a fruit fly body. This technique turned out to be vital to identifying the function of specific genes in different adult organs. Prior techniques to study gene function relied on studying mutants, that is, fruit flies that had a nonfunctioning copy or copies of the gene at

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119. George C. Southworth, *Early History of Radio Astronomy*, 82 SCI. MONTHLY 55, 56 (1956) ("Very important questions arose: How intense is the prevailing static? From what directions does it arrive? How frequently does it appear above the noise inherent in the receiver? It was therefore a thoroughly practical point of view that prompted Karl Jansky's supervisors to give him as his first assignment the study and measurement of static."); Woodruff T. Sullivan, III, *Karl Jansky and the Discovery of Extraterrestrial Radio Waves*, *in* THE EARLY YEARS OF RADIO ASTRONOMY 3, 13 (W.T. Sullivan, III ed., 1984) (quoting Karl Jansky in a letter home on December 21, 1932: "I have taken in more data which indicates definitely that the stuff, whatever it is, comes from something not only extraterrestrial, but from outside the solar system. It comes from a direction that is *fixed in space* and the surprising thing is that it is *the direction towards which the solar system is moving in space.*").

120. Charles H. Townes, *Resistance to Change and New Ideas in Physics*, *in* PREMATURITY IN SCIENTIFIC DISCOVERY, *supra* note 102, at 46, 46–47.

121. Mulkay, *supra* note 106, at 215 ("An important factor contributing to the emergence of this new field of research had undoubtedly been the application of radar techniques by physicists . . . to the established problems of optical meteor astronomy.").

issue. Because many genes are crucial for development, their mutants simply led to embryonic death, thus making it impossible to elucidate their function in adult tissue. In contrast, this new technique allowed the creation of clones of mutant cells in an adult animal, thus bypassing embryonic lethality. Soon, however, the laboratory realized that this technique could be used not only to study the role of particular genes in organ and tissue development and function, but also to mimic cancer. This is because cancer arises precisely when a mutation in a cell in adult tissue creates a clone of mutant cells that grow abnormally. The laboratory went on to shift its focus to use fruit flies as a model to study cancer, thus bringing insights from developmental biology to cancer research.

These examples—the rise of molecular biology and radio astronomy, and the use of fruit flies as a model to study human cancer—tell a story of innovation as the interplay between specialization and cross-fertilization among specialties. But this story is incomplete without analyzing circumstances that often prevent intellectual migration and cross-fertilization, leading to what has been termed "innovative delay."[122]

a. Cognitive impairments to innovation

The first and most apparent source of innovative delay arises from the cognitive hurdles created by the structure of specialization itself. First, specialists unfamiliar with the techniques or the body of knowledge of another field may not be able to evaluate that field's experimental designs and the quality of its results. Second, because specialists in one area are likely to be most familiar with advances in a narrow set of related specialties, they may not even be aware of a particular finding or technological development and its potential implications.[123] An example of this kind of cognitive hurdle leading to innovative delay is the discovery of Big Bang radiation. Prior to its detection by Arno Penzias and Robert Woodrow Wilson, several theoretical papers had

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122. *See, e.g.*, Ernest B. Hook, *A Background to Prematurity and Resistance to "Discovery," in* PREMATURITY IN SCIENTIFIC DISCOVERY, *supra* note 102, at 3, 3–4 (arguing that "considerable social loss may result as a consequence [of delay]").

123. For example, in 1813, William Charles Wells anticipated Charles Darwin's and Alfred Russel Wallace's theory of natural selection. Kentwood D. Wells, *William Charles Wells and the Races of Man*, 64 ISIS 215, 215 (1973). Historians and sociologists of science have postulated that Wells's theory of natural selection had little to no impact because it was buried in an article devoted primarily to other issues. *See, e.g.*, NICHOLAS J. WADE, OBLIVION: THE SCIENTIFIC VISION OF WILLIAM CHARLES WELLS (1757–1817), at 14 (2003).

been published asserting that if there had been a Big Bang, residual radiation noise ought to be detected.[124] But, according to a participant:

> [T]heoretical scientists didn't know much about microwaves, so perhaps they didn't think it could be detected. Almost any radio engineer would have known that if it were as much as predicted, they could detect it. But the theoretical paper wasn't read by engineers or people who were in radio astronomy.[125]

b. Structural impairments to innovation

Sociologists of knowledge have long understood that "people confront the experience of their senses . . . within an already existing structure of knowledge given [to] them by their community and within a structure of purposes sustained by their community."[126] In this context, scientific communities of practice can be understood as providing a background structure of canonical knowledge, experimental techniques, and accepted approaches. This structure *socializes* participants as members of a particular scientific tradition with specific legitimate research questions and methodologies.[127] Membership in a particular community of practice influences how researchers interpret new experimental results and techniques. It also creates a set of vested social interests in the set of skills and theoretical perspectives of their own

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124. Ralph A. Alpher & Robert Herman, *Reflections on Early Work on 'Big Bang' Cosmology*, 41 PHYSICS TODAY 24, 24 (1988) (discussing Ralph Alpher, George Gamow, and Robert Herman's prediction, made in 1951 at a meeting of the American Physical Society, of "a remnant cosmic background radiation in the universe today at a calculated temperature of 5 kelvin"). It was not until 1965 that Arno Penzias and Robert Wilson would observe cosmic background radiation at about three kelvin. *Id.* The original theoretical papers predicting residual radiation noise are: R.A. Alpher et al., *The Origin of Chemical Elements*, 73 PHYSICAL REV. 803 (1948); and Ralph A. Alpher & Robert C. Herman, *Remarks on the Evolution of the Expanding Universe*, 75 PHYSICAL REV. 1089 (1949).

125. Townes, *supra* note 120, at 49.

126. Shapin, *supra* note 94, at 303.

127. *See* Adele E. Clarke & Susan Leigh Star, *The Social Worlds Framework: A Theory/Methods Package*, *in* THE HANDBOOK OF SCIENCE AND TECHNOLOGY STUDIES 113, 116 (Edward J. Hackett et al. eds., 2008) ("The entire act of scientific study is oriented and shaped by the underlying picture of the empirical world that is used. This picture sets the selection and formulation of problems, the determination of what are data, the means to be used in getting data, the kinds of relations sought between data, and the forms in which propositions are cast.").

community—skills that likely required a considerable amount of time and energy to acquire.[128]

Vested interests have an inflationary effect—scientists who belong to a particular scientific tradition will want to display the value of their approach by applying tools and interpretive frameworks to a widening set of problems.[129] Defending a specialty's particular approach often also entails criticizing the value and scope of others' acquired skills and competences. The interplay of these two elements—inflationary pressure to apply tools to other disciplines, and resistance to "outside" tools and interpretive frameworks—helps explain why specialization is both an engine for and a barrier to innovation. Vested interests in a particular specialty can obstruct intellectual migration in two related ways. First, they create personal costs to moving disciplines in addition to learning a new skill set, such as social isolation and loss of social standing.[130] Second, they socialize those within a discipline to be resistant to outsider approaches.[131] More broadly, vested interests can influence the content of research agendas by defining what counts as "interesting" or "legitimate" research projects. When any of this happens, the chances of effective intellectual migration are reduced, and the pace of research progress is slowed.

For example, in the field of radio astronomy, Nobel Prize-winning physicist Charles Townes recounts Professor Bart Bok's social isolation as a radio astronomer at Harvard's Astronomy Department, which caused his subsequent departure.[132] Townes describes how Harvard's Astronomy Department was not enthusiastic about Bok's work "because he had turned from optical to radio astronomy [and the Astronomy Department] didn't think there was much in it."[133] According to Townes, Bok "found it a hard life doing radio astronomy at Harvard, even though he already

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128. *See, e.g.*, Shapin, *supra* note 95, at 164–65 (arguing that many historical scientific debates and controversies can be understood as conflicts between the vested interests of different scientific communities).

129. *See, e.g.*, ROUSE, *supra* note 111, at 87 ("Much scientific research is occasioned not by the felt need to resolve known difficulties in current theory, nor by the desire to uncover such difficulties, but by the concern to take advantage of the available resources in equipment, techniques, trained personnel, and related scientific results.").

130. *See, e.g.*, Townes, *supra* note 120, at 46–47 (describing the social isolation of radio astronomers from mainstream astronomy).

131. *See, e.g.*, ZIMAN, *supra* note 86, at 74 ("A researcher requires a certain standing in a particular field to be entrusted with the facilities, such as apparatus and assistants, to undertake independent research in that field, but this might not be sufficient for him to gain a grant for research in another field to which he or she had not previously contributed.").

132. Townes, *supra* note 120, at 48.

133. *Id.*

had a full professorship."[134] Bok left Harvard's Astronomy Department to join Australia's growing group of scientists who were more receptive to radio astronomical techniques.[135]

Townes is perhaps best known as the leading pioneer in laser and maser technology, for which he obtained two patents.[136] According to Townes, the maser was "based on physical principles well-known since the mid 1920s to physicists familiar with quantum mechanics."[137] Developing the maser required only "putting together [these principles] in the right way."[138] The maser was not developed, however, until the late 1950s.[139] Townes attributes this delay in part to the research priorities and interests of the 1930s physics research community.[140] Maser technology depended on combining well-established optics and spectroscopy research with new insights from quantum mechanics. But by the mid-1930s, "[p]hysicists were moving into nuclear physics. Optics was old stuff."[141] His colleagues tried to dissuade Townes from working on maser technology.[142] Thus, the research agenda developed by the nuclear physics community that marginalized traditional optics research contributed to innovative delay.

An example of structural barriers to innovation in the field of biology is the discovery of the correct chromosome number in 1956 and the subsequent discovery of chromosomal abnormalities in Down syndrome patients.[143] Although experimental techniques to make these discoveries were available in the 1920s in the field of genetics, the vast majority of the genetics community was not interested in medical

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134. *Id.*

135. *Id.*

136. *See* Prod. of Electromagnetic Energy, U.S. Patent No. 2,879,439 (filed Jan. 28, 1958) (laser technology); Masers & Maser Commc'n Sys., U.S. Patent No. 2,929,922 (filed July 30, 1958) (maser technology). Masers and lasers are very similar: masers work in the "microwave" region of the electromagnetic spectrum, while lasers work in its visible or "light" region. *See* '439 Patent; '922 Patent.

137. Townes, *supra* note 120, at 50.

138. *Id.*

139. *Id.* at 46, 51.

140. *Id.*

141. *Id.* at 51.

142. *Id.* at 52.

143. Ernest Hook has posited that the delay in these discoveries, which could have been carried out with a "simple hypotonic treatment, to which there were no apparent cognitive or technical barriers," was due to the structural division of cytogeneticists from physicians. Ernest B. Hook, *Introduction to* PREMATURITY IN SCIENTIFIC DISCOVERY, *supra* note 102, at 3, 13 n.33. Cytogeneticists were not focused upon medical problems, while the vast majority of physicians did not have "sufficient knowledge of and background in the techniques of cytogenetics." *Id.*

problems and did not work with humans or even mammalian material.[144] And the medical community did not have sufficient knowledge of and background in the techniques of cytogenetics.[145]

Resistance to outsider approaches can have a profound influence on the pace of innovation. The birth of bioengineering is an additional example of this type of hurdle. Interviews with engineers who begun to shift their attention to the study of biological materials demonstrates how the slow initial development of the field had as much to do with social barriers as with cognitive ones. First, it was hard to get engineers interested in studying biological materials, which was perceived as risky to one's scientific social status.[146] It was also harder to obtain funds to do research in bioengineering than in either engineering or biology.[147] Finally, other engineers were unsympathetic towards what they regarded as an "unconventional" line of research.[148]

This Subsection focused on how relationships between and among specialties—viewed as a collection of vested interests and cognitive frameworks—influenced the pace of innovation. The next Subsection considers the role of relationships of trust and authority *within* each specialty.

2. TRUST AND AUTHORITY

In the early 1930s, astrophysicist S. Chandrasekhar proposed a theory of stellar degeneration that foreshadowed the discovery of black holes.[149] Owing to the resistance of his one-time mentor and protector—the giant of theoretical physics A.S. Eddington—Chandrasekhar never fully developed or published his theory.[150] The result was that a theory of

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144. *Id.*

145. *See* T.C. HSU, HUMAN AND MAMMALIAN CYTOGENETICS: AN HISTORICAL PERSPECTIVE 15–29 (1979); Malcom Jay Kottler, *From 48 to 46: Cytological Technique, Preconception, and the Counting of the Human Chromosomes*, 48 BULL. HIST. MED. 465, 465–67 (1974).

146. Mulkay, *supra* note 106, at 225.

147. *Id.*

148. *Id.*

149. KAMESHWAR C. WALI, CHANDRA: A BIOGRAPHY OF S. CHANDRASEKHAR 123–24 (1991).

150. Interview by S. Weart with S. Chandrasekhar (May 17, 1977), *available at* http://www.aip.org/history/ohilist/4551_1.html ("[Eddington's] position in astronomy was dominant, what Eddintgon said, was right. I don't think there was any doubt in anybody's mind that Eddington was always right. . . . For example . . . the meeting at which Eddington and I disagreed. I gave a paper and then . . . Eddington came up and said, 'the paper which has just been presented is all wrong.' . . . The other astronomers were certain that my work was wrong because Eddington had said so.").

black holes was not elucidated until thirty years later.[151] Chandrasekhar reflected on Eddington's influence:

> It is quite an astonishing fact that someone like Eddington could have such an incredible authority . . . [that] there were not people who had boldness enough and understanding enough to come out and say Eddington was wrong. . . . I personally believe that the whole development of astronomy . . . [was] delayed by at least two generations because of Eddington's authority.[152]

While the ability of one scientist to single-handedly delay the development of a discipline for thirty years is exceptional, this episode in the history of science illustrates how relationships of authority within a scientific discipline can influence both the direction and the pace of scientific research. I rely on additional examples to illustrate how Chandrasekhar's experience was not an isolated anomaly, but a relatively frequent occurrence in the history of scientific and technological innovation.

Another example, this time from the biological sciences, further illustrates this point. It is now widely accepted that viruses can cause some types of cancer. In the 1930s, however, the research programs of most major research institutes and universities emphasized a hereditary approach to cancer and rejected viral transmission theories.[153] That cancer may arise from a viral infection was so discredited among cancer researchers that "those who held to the theory risked their scientific reputations."[154] This attitude persisted despite evidence that supported a viral transmission model. Indeed, the dominant hereditary model of cancer provided a frame of reference through which cancer researchers interpreted experimental results. Thus, experiments suggesting viral transmission were viewed as incorrectly carried out, while those that rejected it were viewed "real" experimental results.[155] When, in 1936,

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151. WALI, *supra* note 149, at 145 ("It took nearly three decades before the full significance of the discovery was recognized and the Chandrasekhar limit entered the standard lexicon of physics and astrophysics.").

152. *Id.* at 145.

153. Daniel J. Kevles, *Pursuing the Unpopular: A History of Courage, Viruses, and Cancer*, *in* HIDDEN HISTORIES OF SCIENCE 69, 79 (Robert B. Silvers ed., 1995) ("The premise of the Jackson program was that, so far as the occurrence of cancer was concerned, genes counted and viruses did not.").

154. *Id.* at 76.

155. The criteria for counting certain experimental results as valid or credible is influenced by the theoretical expectations of a particular community of practice of what constitutes a correct result. For example, in biology, when it was widely accepted that

John Bittner found that female mice affected with some strains of cancer could transmit the cancer to their offspring through their milk, it seemed reasonable to postulate the existence of a virus in the mother's milk.[156] Still, Bittner called the carcinogenic agent a "milk factor" rather than a virus.[157] Had he called it a virus, Bittner would later remark, "my grant applications would automatically have been put into the category of 'unrespectable proposals.' As long as I used the term 'factor,' it was respectable genetics."[158]

Idealized narratives of scientific research depict disembodied scientific facts standing on their own as proof or disproof of scientific propositions. Sociological narratives, in contrast, show that the path of scientific research cannot be explained without taking into account the role of authority and trust within communities of scientists. Despite modern accounts of science as replacing trust in people with trust in the application of an impersonal scientific method, decisions regarding which experimental evidence is accurate or which research programs are worth pursuing are imbricated with personal considerations.[159] This is particularly the case within scientific subspecialties.

Due to the increasing rate of scientific specialization, the number of scientists who can fully interpret and perform a particular type of work—i.e., a scientific subspecialty—can be surprisingly small. For example, the field of genetics may comprise a large number of researchers, but only a handful of those may focus on using *drosophila* eye tissue as a model to study cancer. Sociologists of science call this group of people who can participate and judge a particular line of work the "core-set." Core-set members form small, specialized communities that are

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bacteria could not exchange genetic material, any evidence of such occurrence was treated as contamination with a different bacterial strain. Harriet Zuckerman & Joshua Lederberg, *Postmature Scientific Discovery?*, 324 NATURE 629, 629 (1986). Similarly, in physics, experiments that showed the existence of fractionally charged objects—at the time considered highly unlikely theoretically—were subjected to intense scrutiny, while experiments finding the opposite were generally considered credible and accepted without much criticism. Andrew Pickering, *The Hunting of the Quark*, 72 ISIS 216 (1981).

156. Kevles, *supra* note 153, at 79.

157. *Id.* at 80.

158. *Id.* at 81.

159. *See, e.g.*, SHAPIN, A SOCIAL HISTORY OF TRUTH, *supra* note 98, at xxv–vi (arguing that reliance upon the testimony of others we trust plays an "ineradicable" role in scientific practice); SHAPIN, *supra* note 93, at 2 (arguing that there is a "pervasive mismatch[]" between "the attributed impersonality of late modern science-making and the rich repertoires of affect-saturated familiarity that one uncovers when looking closely at quotidian institutional practices").

dependent upon each other not only for data, techniques, and research tools, but also, and most importantly, for scientific credibility.[160]

Reliance on trust and authority can serve as a useful heuristic to assess the merits of proposed lines of research or experimental results. But it can also be a source of delay to innovative activity. For example, long before the scientific community recognized that viruses could cause cancer, Ludwik Gross, a medical officer in the United States Army and later a doctor at the Veterans Hospital in the Bronx, had reached the same conclusion.[161] Gross was an outsider to the established cancer research community; he worked alone and subsidized his own research.[162] In 1951 and 1952, he published his experimental evidence that mouse leukemia could be virally transmitted.[163] Although in retrospect his evidence appears indisputable, most cancer researchers did not give it much credence and some questioned Gross's honesty.[164]

Indeed, reliance on the trust/authority heuristic may explain the scientific community's skeptical attitude toward the invention at issue in *Adams*. As the Supreme Court noted, Adams "had worked in his home," and was thus likely an outsider to the relevant community of researchers.[165] It is possible that Adams's status as an outsider, likely with no authority or relationships of trust within the relevant scientific subspecialty, influenced the government expert's negative assessment of the quality of his work.[166]

The last two Subsections examined sociological factors that contribute to innovative delay. The next Subsection examines factors that contribute to scientific "fruitfulness," that is, episodes in the history of science marked by a flurry of research activity in a particular area.

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160. *See, e.g.*, SHAPIN, A SOCIAL HISTORY OF TRUTH, *supra* note 98, at 415; H.M. Collins, *The Place of the 'Core-Set' in Modern Science: Social Contingency with Methodological Propriety in Science*, 19 HIST. SCI. 6 (1981); Ian I. Mitroff, *Norms and Counter-Norms in a Select Group of the Apollo Moon Scientists: A Case Study of the Ambivalence of Scientists*, 39 AM. SOC. REV. 579 (1974).

161. Kevles, *supra* note 153, at 81–84.

162. *See id.* at 82.

163. Hook, *supra* note 122, at 8 n.15.

164. Marcel Bessis, *History of Hematology: How the Mouse Leukemia Virus Was Discovered*, 16 NOUVELLE REVUE FRANÇAISE D'HÉMATOLOGIE, BLOOD CELLS 287, 296 (1976).

165. *United States v. Adams*, 383 U.S. 39, 43 (1966).

166. *Id.* at 44 ("Dr. George Vinal, an eminent government expert with the National Bureau of Standards . . . found 'far from convincing' the graphical data submitted by the inventor . . . .").

3. UNEXPECTED DISCOVERIES

Historians, philosophers, sociologists of science, and scientists themselves have long been interested in the role of unanticipated findings on the pace of innovation. As early as 1679, Robert Hooke attributed the pace and direction of innovation largely to "a luckey bitt of chance, for the most part not in our own power."[167] Almost two centuries later, Louis Pasteur, while acknowledging the role of unexpected findings in innovation, famously warned that "chance only favours the mind which is prepared"[168]—thus emphasizing the importance of scientific skill, rather than luck, in actively noticing an unexpected occurrence. These observations on the role of unexpected results, however, do not take into account the different contexts surrounding the unexpected event. An analysis of historical episodes of unexpected discoveries in scientific progress shows how they can arise in three very different contexts: (1) as true "accidents," (2) as side effects or byproducts extrinsic to the research question under examination, and (3) as anomalous observations intrinsic to the research question under examination. These contexts, in turn, are relevant to determining whether a particular innovation will be unique or discovered simultaneously by multiple researchers.

a. "True" accidents

I term "true" accidents as those discoveries that originate from mistakes or variations in the way research would normally be carried out. A classic and well-known example of this type of unexpected result is Charles Goodyear's discovery of vulcanized rubber.[169] Another example, part of the lore of cancer biology, is the discovery of tyrosine phosphorylation, made possible by the use of an "old" buffer whose pH had changed with repeated use.[170] Because this type of accidental

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167. Alexandre Koyré, *An Unpublished Letter of Robert Hooke to Isaac Newton*, 43 ISIS 312, 320 n.45 (1952) ("The greatest part of Invention being but a luckey bitt of chance, for the most part not in our own power, and like the wind, the Spirit of Invention bloweth where and when it listeth, and we scarce know whence it came, or whether 'tis gone." (quoting ROBERT HOOKE, LECTIONES CULTLERIANAE (1679))).

168. RENÉ VALLERY-RADOT, THE LIFE OF PASTEUR 76 (R.L. Devonshire trans., 1926).

169. *See, e.g.*, Lemley, *supra* note 58, at 733; Franklin C. McLean, *The Happy Accident*, 53 SCI. MONTHLY 61 (1941).

170. Tony Hunter & Walter Eckhart, *The Discovery of Tyrosine Phosphorylation: It's All in the Buffer!*, S116 CELL S35, S37 (2004). Tyrosine is one of the twenty-four aminoacids that are the building-blocks of proteins. *Id.* at S36. Tyrosine phosphorylation is a biochemical event crucial for the transmission of signals inside a cell; it also plays an important role in pathways implicated in cancer. *Id.* at S38. It was

discovery can occur with relative frequency, some scientists even advocate a "controlled sloppiness" approach to research to foster this type of fruitful accident.[171] Yet, the contingent and peculiar circumstances that often surround this type of discovery makes them unlikely to be discovered independently and at the same time by multiple innovators.[172]

b. Byproducts extrinsic to research program

When working to solve a particular research question, unexpected results can arise that are unconnected with the particular question or research program under examination. Sociologists Bernard Barber and Renée Fox reported an instance of this type of unexpected result.[173] When researching the role of particular enzymes ("proteolytic" enzymes) in preventing blood coagulation, two researchers observed that the enzyme papain caused rabbits' ears to become "floppy" for a certain period of time.[174] This was a side effect of papain only, thus seemingly unrelated to the broad effect of proteolytic enzymes on blood coagulation.[175] While both researchers initially showed some interest in elucidating what was causing this floppiness, only one researcher continued studying the problem, eventually finding an explanation.[176] The other regarded floppiness as an amusing side effect of papain treatment that was unrelated to his laboratory's research agenda.[177] A more recent example of this type of unexpected result is the discovery by scientists at the pharmaceutical firm Sanofi in 1972 of products with

not detected earlier because the methods of detection used could not distinguish between tyrosine phosphorylation and the phosphorylation of another aminoacid (threonine), which was known to be phosphorylated. *Id.* at S36. The "aged" buffer with decreased pH allowed this distinction to be made. *Id.* at S38.

171. Salvador Luria noted that "it often pays to do somewhat untidy experiments, provided one is aware of the element of untidiness. In this way unexpected results, sometimes real discoveries, have a chance to come up. When they do, we can trace their cause to the untidy, but known, features of the experiment." Salvador E. Luria, *The T2 Mystery*, 192 SCI. AM. 92, 92 (1955).

172. These are the types of discoveries that Mark Lemley cites as "exceptions" to the prevalence of simultaneous or near-simultaneous invention. *See* Lemley, *supra* note 58, at 733–35.

173. Bernard Barber & Renée C. Fox, *The Case of the Floppy-Eared Rabbits: An Instance of Serendipity Gained and Serendipity Lost*, 64 AM. J. SOC. 128 (1958).

174. *Id.* at 130.

175. *Id.*

176. *Id.* at 132–33.

177. *Id.* at 134–35.

anticoagulation properties while looking for products with enhanced anti-inflammatory properties.[178]

Although side effects, especially if consistent and easily detectable, may be discovered simultaneously, investigating the unexpected result requires the investigator to deviate from his research agenda. Additionally, taking advantage of the unexpected observation may be particularly tricky, since it has no clear connection to the research question under examination and may require expertise that the researcher does not possess. Thus, while observation of the unexpected result may happen in multiple independent laboratories more frequently than is the case with "true" accidents, unexpected results that are byproducts of a research program are also likely to be relatively unique.

c. Anomalous observations intrinsic to research program

A third type of unexpected result, however, is both more likely to be discovered simultaneously by independent researchers *and* to be actively investigated by them. This is the case of observations that contradict expectations in a planned research program. An example of this type of unexpected result is the discovery of reverse transcription, that is, the existence of enzymes that could make DNA *from* ribonucleic acid (RNA). This discovery contradicted conventional wisdom, which held that DNA made RNA, which in turn made protein in a linear, nonreversible sequence.[179] When studying tumor viruses, David Baltimore isolated an unusual enzyme that appeared to make DNA from RNA.[180] Simultaneously with Baltimore's lab, Howard Temin found evidence that RNA viruses could synthesize DNA.[181] These anomalous observations were pursued enthusiastically by both laboratories, both of them aware of their momentous implications for molecular biology.[182]

A second example is the unexpected result in *Sanofi-Synthelabo v. Apotex*,[183] that a particular form (an "enantiomer"[184]) of a compound

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178. *Sanofi-Synthelabo v. Apotex, Inc.*, 550 F.3d 1075, 1078 (Fed. Cir. 2008).

179. This conventional wisdom that information travels on a one-way street from DNA to RNA to protein was so strongly held that it was termed the "central dogma" of molecular biology. *See Destroying Dogma: The Discovery of Reverse Transcriptase*, ROCKEFELLER U., http://centennial.rucares.org/index.php?page=Destroying_Dogma (last visited Mar. 9, 2013).

180. *Id.*

181. *Id.*

182. *Id.*

183. 550 F.3d 1075 (Fed. Cir. 2008).

184. Enantiomers have the same chemical formula, but a different three-dimensional structure. *See id.* at 1080–81. Specifically, they are mirror images of each other and are known to have different biological activities. *See id.*

showed enhanced therapeutic activity with no toxicity.[185] Defendant Apotex argued that because enantiomers are known to have different biological activities, a research program attempting to reduce toxicity would try to isolate different enantiomers of the compound under investigation.[186] Assuming this is the case, the fact that one of these enantiomers was unexpectedly found to have *none* of the toxic effects with *all* the therapeutic effects—while unexpected—would likely have been noticed by any independent scientist pursuing this research program. In addition, the low likelihood of finding one enantiomer with all the therapeutic benefits and none of the toxic effects did not ex ante discourage the line of research that would attempt separation of the enantiomers. In other words, the label "unexpected results" in this case does not serve as a proxy for identifying a risky line of research that requires patent inducement.[187]

Anomalous observations of this type are the *sine qua non* of scientific research. They are exciting, research generating, and attention grabbing—likely to be noticed by all researchers working on a particular line of research—precisely because they contradict what they expected to find. This type of anomalous results intrinsic to a research program is also likely to generate fruitful follow-on research. Thus, granting broad patents to this type of unexpected discoveries may have a particularly deleterious impact on follow-on innovation. I explore in more depth the implications of these three types of unexpected results for obviousness theory and doctrine in Part III.

B. The Science/Technology Distinction

Many of the discoveries and innovations described in the preceding Section, such as the discovery of DNA, black holes, and the viral transmission of cancer, happened in an academic setting and involved what may be labeled as "basic science." This raises the question of whether the social constraints and accelerants to innovation exemplified

185. *Id.* at 1081.

186. *Id.* at 1086–87.

187. Some scholars endorse the use of "unexpected results" as a proxy for high-risk projects. *See, e.g.*, Abramowicz & Duffy, *supra* note 10, at 1671–72 ("The focus on unexpected results, for example, is consistent with the point that low probability experimentation should generally be rewarded . . . ."); Merges, *supra* note 21, at 40–42. While some projects leading to unexpected results are risky—and may thus be delayed absent the inducement of a patent—the label "unexpected results" is overinclusive. It signals risky projects *only* when researchers know *before* engaging in a research program that it is unlikely to succeed. In this context, results are unexpected in light of this low probability of success.

by these case studies are applicable to the domain of technology—i.e., to those useful embodiments of basic science that patent law is designed to incentivize.

The categories of "science" and "technology," however, are hard to delineate precisely, and several of the discoveries described above (such as laser and maser technology) indeed represent patentable innovations. In particular, the concept that basic science takes place in academia and that technological development does so in industrial settings is an inaccurate description of the current organizational structure of innovation.[188] In practice, both types of institutional contexts perform a combination of basic and applied research.[189] Drawing a distinction between these two categories is often not only "difficult to make [but also] meaningless in practice."[190]

More importantly for the purpose of this Article, for a large number of patentable technologies, such as pharmaceuticals, biotechnology, and products of mechanical engineering, practitioners were trained in traditional academic fields and are likely to retain the vested interests of their specialized training. For example, at Bell Laboratories, the distinct disciplinary identities and backgrounds of its employees were identified as potential sources of breakthrough innovation, provided different communities of practice were simultaneously induced to interact and prevented from remaining in their disciplinary silos.[191] Thus, buildings at Bell Laboratories were "connected as to avoid fixed geographic delineation between departments and to encourage free interchange and close contact among them. The physicists and chemists and mathematicians were not meant to avoid one another . . . . By intention, everyone would be in one another's way."[192]

Finally, the concept of "communities of practice" or "communities of innovation" is useful to explain more broadly how specialized knowledge—outside of academic disciplines and subdisciplines—is created, organized, maintained, and diffused. Communities of practice

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188. SHAPIN, *supra* note 93, at 18–19 ("[M]any standard contrasts between late modern academic and industrial science are poorly founded. . . . [I]nstitutional realities—both academic and corporate—have always been so heterogeneous that the contrasts [between basic science and technology] that have the greatest grip on our minds are not those between the range of mundane institutional realities but between ideal types.").

189. *Id.* at 97–98.

190. *Id.* at 97 ("[T]he clear divide between pure and applied, and between the institutions in which these supposedly different form of inquiry were housed . . . seemed to have made little sense to industrial scientists and those who managed their labors in the first part of the twentieth century.").

191. JON GERTNER, THE IDEA FACTORY: BELL LABS AND THE GREAT AGE OF AMERICAN INNOVATION 76–77 (2012).

192. *Id.* at 77.

form through social interactions among people who pursue a common class of problems.[193] Over time, they come to embody a store of knowledge and tools.[194] New community members learn the "sociocultural" practices of communities through interaction with established members.[195] For example, Eric von Hippel describes user innovation communities as "often stocked with useful tools and infrastructure that increase the speed and effectiveness with which users can develop and test and diffuse their innovations."[196] Importantly, he also describes innovations as often taking place when members in two different communities combine "previously disparate elements."[197]

III. APPLICATIONS

Patent law acts against a backdrop of social forces that both constrain and motivate innovators. These forces, and not only the competitive baseline, shape the pace and content of innovation. This Part examines how taking into account the insights from sociology and the history of science explored in Part II impacts both patent law theory and doctrine. The emphasis throughout is on how specialization, trust and authority, unexpected discoveries, and embedded knowledge affect the *timing* of innovation. This focus understands patent law as seeking to induce earlier innovation and is in line with current law and economics analysis on the role of patents.[198]

Law and economics scholarship on patent law seeks to define the competitive baseline in order to identify those inventions that would have come about at approximately the same time without patent protection. For example, a rapid decline in the cost of innovation or a sharp rise in demand immediately preceding an invention is taken as evidence that competition alone is sufficient to stimulate innovation.[199] A

193. *See, e.g.*, Etienne Wenger, *Communities of Practice and Social Learning Systems*, 7 ORGANIZATION 225, 229 (2000).

194. *Id.*

195. LAVE & WENGER, *supra* note 104, at 29.

196. ERIC VON HIPPEL, DEMOCRATIZING INNOVATION 93 (2005).

197. *Id.* at 94.

198. *See, e.g.*, Abramowicz & Duffy, *supra* note 10, at 1626 ("More generally, the patent system is frequently modeled as a system designed to produce not more innovation but earlier innovation."); John F. Duffy, *A Timing Approach to Patentability*, 12 LEWIS & CLARK L. REV. 343 (2008).

199. *See, e.g.*, Abramowicz & Duffy, *supra* note 10, at 1656; Durie & Lemley, *supra* note 10, at 1002–03 ("One of the reasons an invention might be made at a particular time and not before is not that it was hard or unforeseen, but that some sort of exogenous shock, such as the development of a new collateral technology, made it either desirable or feasible for the first time.").

socio-historical approach can be understood as defining the "social baseline"—that is, aspects of social structure that both facilitate and delay innovation. Together with the competitive baseline, it provides a fuller understanding of the context of invention. In turn, this better understanding of the context of invention can help both critique and refine existing proxies for identifying patentable inventions.

A. Theories of Obviousness through a Socio-historical Lens

1. THE SOCIAL DIMENSION OF RISK AND CHOICE

An economic theory of obviousness that conceptualizes patents as rewarding innovators who pursue uncertain and risky projects—as advocated by Landes, Posner, and Merges[200]—should take into account the social dimension of risk. Similarly, a full understanding of the factors that affect choice among research projects—as required by Meurer's and Strandburg's theory[201]—necessitates understanding not only the economic and technical hurdles that make a project more costly or more technically difficult, but also the social context that influences research choice.

For example, the case studies described previously show how the interplay between scientific specialization and intellectual migration often drives innovation. Yet, the set of vested interests in particular scientific approaches is likely to make migration difficult. In other words, deciding to change scientific specialties or applying tools or principles from one specialty to another can be personally risky. At a minimum, it will certainly require a certain amount of retooling. And colleagues from the new specialty may not be able to fully appreciate or interpret the results generated, or may simply be biased against such outside research tools or approaches. The same set of social risks likely applies at the institutional level, both in the case of a firm with a specialized niche area or with different specialized in-house departments. Although movement of personnel and ideas from one specialty to another is likely innovation-enhancing, the case studies examined in Part II suggest that there are likely to exist persistent social barriers to cross-disciplinarity, making this type of project inherently riskier and costlier to pursue.

Pursuing a particular line of research in the face of opposition or disbelief from members of the core-set of experts whose opinion is

200. *See supra* Part I.B.1.
201. *See supra* Part I.B.2.

important for securing scientific credibility is also particularly risky. A line of research that is based on experiments that are accorded low credibility is risky because it will likely require more work to convince skeptics of the soundness of the underlying data. These unconventional lines of research are also likely to be underfunded. Thus, core-set views on which problems are interesting or legitimate will also influence decisions regarding which research programs are worth investing in.

Finally, one can plausibly think of research into the subset of unexpected results that are the byproducts of a research program as entailing a particular type of risk.[202] It is often the case that the utility, importance, or explanation for these unexpected results is not easily ascertained because the results are unconnected with the question under investigation. Thus, turning these unexpected results into fruitful discoveries usually requires a detour from a particular, usually more established, research line into a more uncertain (and thus risky) one.

The larger point here is that the pace of innovation is influenced by the social structures in which innovation is practiced. Thus, a fully developed theory of obviousness as rewarding risk taking, or as influencing choice among research programs, should incorporate this social dimension.

2. THE SOCIAL DIMENSION OF INDUCEMENT

In seeking to operationalize the inducement standard of patentability, Duffy and Abramowicz argue for abandoning a cognitive view of obviousness in favor of an economic perspective.[203] A socio-historical perspective is also critical of the cognitive approach to defining a PHOSITA favored by courts, but for different reasons than those emphasized by Abramowicz and Duffy's economic approach. Both the Federal Circuit and the United States Supreme Court have long been concerned with differentiating those possessing "ordinary" skill from those having "extraordinary" skill in the art.[204] The latter group of workers is thought to possess "something" that set them apart from their

202. *See supra* Part II.A.3.b.

203. Abramowicz & Duffy, *supra* note 10, at 1603–12.

204. *See, e.g.*, *Standard Oil Co. v. Am. Cyanamid Co.*, 774 F.2d 448, 454 (Fed. Cir. 1985) (describing a PHOSITA as a person who "thinks along the line of conventional wisdom in the art and is not one who undertakes to innovate, whether by patient, and often expensive, systematic research or by extraordinary insights"); *Kimberly-Clark Corp. v. Johnson & Johnson*, 745 F.2d 1437, 1454 (Fed. Cir. 1984) (emphasizing that the PHOSITA cannot be equated with the inventor, who is presumptively a person of extraordinary insight or skill).

more ordinary-skilled counterparts.[205] That "something" has traditionally been conceived in cognitive terms: persons of extraordinary skill were simply better able to conceptualize nonobvious inventions. Thus, a cognitive view of obviousness tries to ascertain the degree of cognitive difficulty in coming up with the invention by asking whether the "ordinary" worker would have been able to develop it.

But what a myriad of case studies on scientific innovation show is that the making of the vast majority of scientific knowledge "can be sufficiently accounted for by ordinary human cognitive capacities and ordinary forms of social interaction."[206] In other words, most knowledge is truly incremental and attempting to identify those inventions deserving of patent protection by seeking to reward extraordinary insights is not only based on empirically inaccurate assumptions, but is also impossible to operationalize. A socio-historical approach recognizes that barriers to invention are often structural (for example, driven by specialization) and not cognitive. A cognitive approach, however, is useful insofar as it outlines the set of tools and background knowledge available to those likely to encounter a particular research problem.

Duffy and Abramowicz take innovative delay itself as a strong marker of nonobviousness.[207] In their model, inventions are nonobvious *unless* certain specific circumstances (such as a surge in demand for the invention or a collateral technological breakthrough shortly before the invention) suggest the invention would likely have been developed soon afterwards without the need for a patent incentive.[208] What does a sociological approach add to this analysis? First, it provides an explanation for cases of innovative delay in which a review of the then-available technology and know-how would have predicted an earlier invention date. Being able to explain *why* a particular innovation was

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205. *See, e.g.*, *Standard Oil Co.*, 774 F.2d at 454 ("Inventors, as a class, according to the concepts underlying the Constitution and the statutes that have created the patent system, possess something—call it what you will—which sets them apart from the workers of *ordinary* skill . . . .").

206. Shapin, *supra* note 94, at 305.

207. Abramowicz & Duffy, *supra* note 10, at 1630 (discussing Judge Richard Posner's panel decision in *Roberts v. Sears, Roebuck & Co.*, 723 F.2d 1323 (7th Cir. 1983), and emphasizing that the gap of three-and-a-half decades between "the patent that Posner heralded as having all the essential elements needed to make [the] invention" and the invention itself should have been strong evidence of nonobviousness).

208. *Id.* at 1600 (explaining that "circumstances that make a patent-motivated innovator insignificantly better (that is, insignificantly earlier) than an innovator not motivated by the patent system . . . can serve as proxies for the inducement standard," and identifying "a positive demand shock shortly before the invention" and the "development of a technology that is an input into the new technology" as two such proxies).

delayed, as well as understanding the role that patent incentives can play in accelerating such an innovation, makes granting a patent to those likely-to-be delayed inventions an easier case.

The harder question is what a sociological approach has to say about those inventions for which no sociological explanation of delay is available. Of course, there will often be economic explanations for such a delay: for example, the project may have simply been too costly or too technically challenging. Importantly, however, a sociological approach also suggests circumstances in which social forces may accelerate innovation—making patent incentives less important. I have suggested that the discovery of anomalies within a research program is one such case. Additionally, the research priorities of a community of practice can shift not only because of a surge in market demand or a collateral technological advance, but also because of internal social dynamics within the relevant community. Specifically, a particular line of research long considered uninteresting or illegitimate may become a "hot" topic of research, or a boundary between communities of practice may be eroded to the point that a new cross-cutting community emerges.[209] Thus, a surge in cross-community teamwork, or a shift in the internal research priorities of a community of practice shortly before an invention may often obviate the need for patent incentives.

Patent law doctrine already incorporates some of these insights by considering whether prior art taught away from the invention, whether the invention was met with skepticism, or whether it was the product of unexpected results.[210] A nuanced understanding of how specialization, trust, authority, and unanticipated findings influence innovation, however, provides a richer justification for employing these heuristics,

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209. *See, e.g.*, Scott Frickel & Neil Gross, *A General Theory of Scientific/Intellectual Movements*, 70 AM. SOC. REV. 204, 205–06, 208 (2005) (Scott Frickel and Neil Gross develop a general theory of "scientific/intellectual social movements" (SIMS), defined as "collective efforts to pursue research programs or projects for thought in the face of resistance from others in the scientific or intellectual community." SIMS often "problematize previously undiscussed or underdiscussed topics," or "alter the boundaries of existing scientific or intellectual fields." Although initially faced with resistance, many SIMS ultimately "gain adherents, win intellectual prestige, and . . . acquire . . . institutional stability."); Fujimura, *supra* note 95, at 261 ("A scientific bandwagon exists when large numbers of people, laboratories, and organizations commit their resources to one approach to a problem.").

210. *See, e.g.*, *Transocean Offshore Deepwater Drilling, Inc. v. Maersk Contractors USA, Inc.*, 617 F.3d 1296, 1303–05 (Fed. Cir. 2010) (discussing industry skepticism as supporting a finding of nonobviousness); *Depuy Spine, Inc. v. Medtronic Sofamor Danek, Inc.*, 567 F.3d 1314, 1324–25 (Fed. Cir. 2009) (relying on evidence that the prior art taught away from the invention); *Sanofi-Synthelabo v. Apotex, Inc.*, 550 F.3d 1075, 1086–87 (Fed. Cir. 2008) (relying on evidence of "unexpected properties" to support a finding of nonobviousness).

criticizes some contexts in which they are used, and suggests several refinements to obviousness doctrine. I turn to these in the next Section.

B. Obviousness Doctrine

Understanding innovation as both driven and hindered by the social context in which it takes place suggests several modifications to obviousness doctrine. First, the obviousness inquiry should be structured so as to reward, and thus incentivize, those inventions that transport ideas, techniques, and problems across disciplinary boundaries, especially when vested interests are likely to delay or block fruitful intersections between communities of practice. In practice, this means that charting the precise contours of analogous art should take center stage in determinations of obviousness. The emphasis should be on whether a PHOSITA in the relevant community of practice would have considered the specific references at issue and on how much consideration he would have given each one of them. Second, courts may consider evidence demonstrating that the inventor used tools or insights from other disciplines in coming up with the invention as additional indicia of nonobviousness. This prescription is subject to an important caveat that takes into account private responses to the specialization problem. Where interdisciplinary team approaches to problem solving are the norm, patent law may not need to play an important role in stimulating cross-disciplinarity. In this case, a team having ordinary skill in the art may be the appropriate unit of analysis. Third, persistent skepticism from the core-set of experts in the field is an important secondary consideration, especially if the researcher or firm pursuing the invention is not part of such core-set. Fourth, unexpected results that arise as anomalous observations related to the research question being analyzed are not a good proxy for the uniqueness of an invention. In this case, the key question is whether patent law was needed to stimulate the particular line of research leading to the unexpected result (i.e., to stimulate a race for the patent), not whether the results themselves were unexpected. I examine each of these prescriptions in more detail below.

1. REDEFINING A PERSON HAVING ORDINARY SKILL IN THE ART AND THE CONTOURS OF ANALOGOUS ARTS

In a socio-historical approach, understanding the community of practice in which a person of ordinary skill in the art is embedded is of paramount importance. It is only through understanding this community that we can know the research interests and priorities of a person having ordinary skill in the art, the types of tools she is likely to use, the network of other researchers she is more or less likely to interact with, and the literature she is more or less likely to consult. Yet, Federal Circuit jurisprudence has traditionally paid little attention to carefully defining the PHOSITA. Instead, defining a PHOSITA is usually limited to reciting a set of possible resume qualifications.[211]

Understanding the types of questions a PHOSITA is likely to ask and how she is likely to approach answering them also requires paying close attention to what constitutes "analogous prior art."[212] The doctrine of analogous prior art serves to limit the types of prior art references under examination when determining whether an invention is obvious.[213] Before *KSR*, it was invoked infrequently because the TSM test usually required that the prior art explicitly suggested a particular combination of references, essentially "directing" the inventor to consult particular pieces of prior art.[214] By emphasizing that "design incentives and other market forces can prompt variations of [a work available in one field of endeavor], *either in the same field or in another*,"[215] the Court in *KSR* took an expansive view of what constitutes analogous prior art. If there is a problem to be solved, the Court suggested, a PHOSITA would use all tools available, from any discipline, to solve it. Indeed, the Federal Circuit in *Wyers v. Master Lock Co.*[216] interpreted *KSR* as "constru[ing] the scope of analogous art broadly."[217]

Yet, in its more recent opinions, the Federal Circuit has taken a narrower and more formalistic view of analogous art. For example, in *In re Klein*,[218] the court considered whether two types of prior art references constituted analogous prior art.[219] The inventor in *In re Klein* had designed a bird feeder with moveable dividers that allowed for the quick

211. *See, e.g.*, Durie & Lemley, *supra* note 10, at 1000 (noting that "explicit factual determinations of the PHOSITA's skill have been rare").

212. *See, e.g.*, *Innovention Toys, LLC v. MGA Entm't, Inc.*, 637 F.3d 1314, 1321 (Fed. Cir. 2011) ("A reference qualifies as prior art for a determination under § 103 [obviousness] when it is analogous to the claimed invention."); *In re Bigio*, 381 F.3d 1320, 1325 (Fed. Cir. 2004).

213. A reference is considered "analogous prior art" (1) if it "is from the same field of endeavor, regardless of the problem addressed and, (2) if the reference is not within the field of the inventor's endeavor, [if it] still is reasonably pertinent to the particular problem with which the inventor is involved." *In re Bigio*, 381 F.3d at 1325.

214. *See, e.g.*, Durie & Lemley, *supra* note 10, at 1016 n.145.

215. *KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398, 401 (2007) (emphasis added); *see also id.* at 402 ("[F]amiliar items may have obvious uses beyond their primary purposes, and a person of ordinary skill often will be able to fit the teachings of multiple patents together like pieces of a puzzle.").

216. 616 F.3d 1231 (Fed. Cir. 2010).

217. *Id.* at 1238.

218. 647 F.3d 1343 (Fed. Cir. 2011).

219. *Id.* at 1351–52.

and easy preparation of sugar water solutions with different concentration of sugars, thus appealing to different bird species.[220] The invention relied on a moveable divider to adjust the ratio of sugar and water.[221] Moving the divider changed the relative size of the sugar and water compartments.[222] Subsequent removal of the divider allowed for the mixing of sugar and water creating solutions of different degrees of sweetness.[223] Two types of prior art references were considered. The first concerned the design of moveable dividers to create differently sized compartments in, for example, tool trays and cabinet drawers.[224] The second concerned fixed dividers separating two types of fluid, or a fluid and a solid, which could be mixed by removing the divider.[225] The two types of references taught different aspects of the invention. The first type of prior art taught how to make moveable dividers; the second, how to use dividers to keep a liquid and a solid separate until ready to be mixed. The court concluded that these prior art references did not constitute analogous prior art, in essence, because they did not directly address every aspect of the problem being solved.[226] In so doing, it developed a rule that is in tension with *KSR*'s expansive wording.[227]

Neither approach to defining analogous arts is supported by sociological and historical evidence on how innovation actually happens. The first pays little attention to cognitive and structural barriers that hinder cross-disciplinarity. The second neglects to consider that, if the prior art at issue happened in cognate fields, an inventor would likely have the ability to combine multiple references that teach separate aspects of the invention. It thus erects a fictitious and unrealistic division between discoveries within a field of endeavor and those "reasonably pertinent" to the invention.

An emphasis on communities of practice would instead focus first on defining the network of social interactions that constitutes the "core" and "periphery" of the community. This inquiry would seek to answer the questions: Who does a PHOSITA interact with? What types of publications does she read? A reference would constitute analogous art if

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220. *Id.* at 1345.

221. *Id.*

222. *Id.*

223. *Id.*

224. *Id.* at 1350.

225. *Id.* at 1351.

226. *Id.* at 1350–52.

227. *See KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398, 402 (2007) ("[F]amiliar items may have obvious uses beyond their primary purposes, and a person of ordinary skill often will be able to fit the teachings of multiple patents together like pieces of a puzzle.").

it is within the core and peripheral networks. Second, it would recognize that a PHOSITA would make attempts to go outside her field to solve particular problems, in particular if there are few cognitive or structural barriers to cross-disciplinarity (e.g., there is no need for retooling, the other field is easy to understand and learn). This inquiry can be captured by the analogous art test as currently formulated, but *without* the limitation adopted by the Federal Circuit in *In re Klein* that appears to require that a reference in an analogous field address every aspect of the invention at issue. Had the court in *In re Klein* actually focused on defining the relevant communities of practice, it would likely have reached the same conclusion—namely, that the references at issue were not "analogous art" to the bird-feeder invention under review—without crafting a new rule. Specifically, two references under consideration—one concerning a "Blood Plasma Bottle" for use in a medical context and the other a "Fluid Container" for use in mixing hair rinses—are unlikely to be the type of reference that a member of a community of bird-feeder designers would have access to.[228]

Most importantly, determining whether a reference constitutes analogous prior art would not end the inquiry. Rather than conceptualizing the analogous art doctrine as an on/off switch, whereby all analogous art references are treated equally, a socio-historical approach would recognize the differential impact that different pieces of prior art are likely to have on future research. Each reference would be analyzed to determine the strength of its influence. Being squarely in the core of the community's network would increase the strength of a reference, because it would increase the likelihood that a PHOSITA would be familiar with it and take it into account in future research. But other factors would also be relevant. For example, a court may consider: (1) whether the reference was published in a high-impact publication in the field or in an obscure medium,[229] (2) whether it was presented using

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228. *In re Klein*, 647 F.3d at 1351. Whether a member of a community of bird-feeder designers would have had access to the remaining references—including a tool tray with moveable dividers "for the purpose of keeping tools and other construction items . . . separated," and a cabinet drawer with removable dividers "for the purpose of keeping small household articles . . . separated"—is a harder question. *Id.* at 1350. A court could find that tool-organizers are so widely available and displayed in hardware stores that they would be well known to members of the bird-feeder design community.

229. *See, e.g.*, Benjamin F. Jones, *The Burden of Knowledge and the "Death of the Renaissance Man": Is Innovation Getting Harder?*, 76 REV. ECON. STUD. 283, 309–10 (2009); Jones, *supra* note 100, at 1–2 (describing the explosion in the number of scientific publications, which expand at an average rate of 5.5% per year, making it impossible for any scientist to be familiar with all relevant literature). It is likely that, when faced with this increasing burden of knowledge, researchers will seek shortcuts to

difficult to understand or atypical terminology,[230] and (3) whether it was buried in an article devoted primarily to other issues.[231] Thus, a reference in the core field of inquiry that was published in an obscure outlet may be weaker than a reference in the periphery that received wide publicity.

Features other than the bare factual content of a reference influence its reception by the relevant community of practice. Factors that decrease the strength of a reference (e.g., its low probability of being read, understood, appreciated, or considered credible by the relevant community of practice) are likely to delay innovation.[232] These types of references should accordingly be given less weight in the obviousness inquiry.

Finally, evidence that an inventor used tools or insights from other nonanalogous disciplines in making the invention can serve as additional indicia of nonobviousness. For example, the presence of multiple inventors in a patent—each with a publication record or with training in different fields of study—could serve as objective indicia of nonobviousness, provided the inventors can explain how knowledge from each one of their distinctive communities of practice contributed to the invention. Evidence that the invention crossed disciplinary fields would be particularly relevant if accompanied by indications that there exist cognitive or structural barriers between the two fields. Using evidence of intellectual migration as a secondary consideration of obviousness, however, requires sharply delineating the content of analogous arts. Define analogous prior art too broadly, and a discipline-crossing invention worthy of a patent may be missed. Define it too narrowly, and a patent may be granted on a routine combination of elements. Additionally, this prescription is subject to an important caveat: in fields where research is routinely carried out by teams whose members have different disciplinary backgrounds, the appropriate unit of analysis may be the "team" having ordinary skill in the art.

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determine which articles to read, including reading only articles published in well-established venues.

230. For example, the "constrained and somewhat idiosyncratic style" of mathematician Evariste Galois is thought to have contributed to the delayed recognition of his significant contributions to mathematics. Hook, *supra* note 122, at 5 n.6.

231. Some have attributed the negligible impact of William Charles Well's anticipation in 1813 of Darwin's and Wallace's theory of evolution by natural selection to its publication in an article devoted largely to other topics. *See supra* note 123. *But see* RICHARD HARRISON SHRYOCK, MEDICINE IN AMERICA: HISTORICAL ESSAYS 259, 263 (1966).

232. By "delay," I refer to delay when compared to the hypothetical situation in which the reference(s) at issue are well-known, well-regarded, and incorporated into the "core" canon of the relevant community of practice.

The hurdle to innovation posed by increasing specialization has long been recognized by industry, universities, and government research laboratories. Empirical data suggests that the rapid expansion of scientific knowledge, as evidenced by the steady growth in the number of articles published in the science and engineering fields, is causing individual scientists to seek narrower fields of expertise.[233] Importantly, this rise in specialization correlates well with a declining tendency to switch disciplines or subdisciplines.[234] This correlation suggests that individuals are not only more specialized, but also that it is increasingly unusual for a single individual to be trained in more than one discipline. In turn, the inability of individuals to cross disciplinary boundaries is correlated with a decrease in high-impact ideas (as measured by the number of median citations to publications or patents).[235] This data provides strong empirical support for the socio-historical model of innovation described in Part II, which understands innovation as the interplay between specialization and migration. A third trend, however, counteracts the increasing specialization of individual inventors: the rise of teamwork. Interestingly, members of a team show no decline in their ability to move between specialized fields. In addition, teamwork results in more high-impact publications and patents.[236]

Private industry, government, and academic research laboratories have all taken steps to increase interdisciplinarity. For example, the National Institutes of Health is currently building an interdisciplinary neuroscience facility.[237] Research universities have sought to create multidisciplinary training programs,[238] and there is a burgeoning field of laboratory design that focuses on creating open spaces to foster

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233. Jones, *supra* note 100, at 1–2.

234. *Id.* at 13 fig.4A (plotting the decreasing "tendency for a solo inventor to switch technological areas across that inventor's consecutive patents" from 1975 to 1993).

235. *Id.* at 11–14.

236. *Id.* at 14.

237. *See* Carla Garnett, *Final Part of Bldg. 35, 'Porter II' Nears Groundbreaking*, NIH REC., Aug. 20, 2010, at 1, 6, *available at* http://nihrecord.od.nih.gov/pdfs/2010/08202010_Record.pdf (describing the "Porter II" neuroscience building).

238. For example, both Harvard University's and Yale University's graduate programs in the biological sciences are administered through Biological and Biomedical Sciences interdepartmental programs. *See Biological and Biomedical Sciences*, HARVARD MED. SCH., http://www.hms.harvard.edu/dms/bbs/ (last visited Mar. 5, 2013); *Biological and Biomedical Sciences*, YALE UNIV., http://bbs.yale.edu/index.aspx (last visited Mar. 5, 2013).

interaction and interdisciplinarity.[239] How much these efforts have combatted the trend towards increasing specialization and fomented cross-disciplinarity is an open question. In most academic settings, for example, faculty still associate with individual departments and members of a single lab tend to be quite similar in their background and expertise.

But to the extent that these private responses to the specialization problem, including the rise of teamwork, are successful in fostering interdisciplinarity, they should be taken into account in the obviousness inquiry. If teams are routinely engaged in cross-disciplinary research, patent law may not be as important a tool to foster intellectual migration. Further, to the extent that teamwork becomes the routine approach in a particular field of inquiry, the appropriate unit of analysis for the obviousness inquiry may no longer be a person having ordinary skill in the art but rather a team having ordinary skill in the art (THOSITA). A PHOSITA will not capture the breadth of interests and approaches that may have become commonplace in that particular field. On the other hand, in areas where interdisciplinary teamwork is unusual, or for particularly novel combinations of specialties, the ex ante knowledge that a patent will reward interdisciplinary efforts can spur the costly and likely risky enterprise of bringing together the rare team.[240]

2. SECONDARY CONSIDERATIONS OF NONOBVIOUSNESS

KSR's departure from the more formalistic TSM test provided lower courts with little guidance on how to operationalize the obviousness inquiry. In the context of the relatively straightforward subject matter concerning the patent at issue in *KSR*—the design of an adjustable pedal—it was easy to see how application of "common sense" may lead to a finding of obviousness.[241] But it is harder to use "common sense" when dealing with complex technologies. Secondary considerations of nonobviousness can provide useful guidance in these cases. The Federal

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239. *See, e.g.*, Daniel Watch, *Trends in Lab Design*, WBDG, http://www.wbdg.org/resources/labtrends.php (last updated Sept. 19, 2012) (noting how the design of laboratory space is driven by the "need to create '*social buildings*' that foster interaction and *team-based research*").

240. Teams may also emerge simultaneously or near-simultaneously in a race to obtain a patent. When using a THOSITA as the relevant unit of analysis (rather than a PHOSITA) it will be important distinguish between cross-disciplinary teams that have formed at around the same time to race for a patent, and those that reflect a shift in the background, "routine" ways of doing science.

241. *KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398, 402 (2007) ("It is common sense that familiar items may have obvious uses beyond their primary purposes, and a person of ordinary skill often will be able to fit the teachings of multiple patents together like pieces of a puzzle.").

Circuit has often relied on secondary considerations, frequently invoking "unexpected results,"[242] "teaching away,"[243] or "skepticism"[244] as indicia of nonobviousness. A socio-historical approach can help refine these secondary considerations and propose additional ones.

a. Persistent skepticism and innovative delay

Pursuing research proposals that the relevant scientific community's core-set considers unworkable or uninteresting, or that are based on results this core-set considers unconvincing, is socially risky. In turn, innovations resulting from socially risky projects are likely to be delayed. Patent incentives can serve to partially offset this innovative delay by considering circumstances that are likely to delay invention as indicia of nonobviousness. The obviousness inquiry already incorporates "skepticism" as one of several considerations of nonobviousness. An obviousness inquiry based on a socio-historical understanding of science, while providing support for relying on skepticism as a marker of nonobviousness, would also require a more in depth factual analysis of the circumstances surrounding such skepticism.

Skepticism is also part and parcel of routine research. It is a crucial component of the intellectual exchange within communities of practice, serving as a quality control mechanism that forces investigators to back up their claims with credible evidence.[245] As a result, most discoveries are likely to be met with a certain degree of skepticism from practitioners. Peers scrutinize each other's work; journal editors reject manuscripts whose data they consider insufficiently justified. Indeed, "organized skepticism" is one of the norms proposed by Merton as constituting the "ethos" of academic science.[246] It also operates regularly

242. *See, e.g.*, *Sanofi-Synthelabo v. Apotex, Inc.*, 550 F.3d 1075, 1085–90 (Fed. Cir. 2011) (relying on evidence of "unexpected properties" to support a finding of nonobviousness); Harris A. Pitlick, *Some Thoughts about Unexpected Results Jurisprudence*, 86 J. PAT. & TRADEMARK OFF. SOC'Y 169 (2004).

243. *See, e.g.*, *United States v. Adams*, 383 U.S. 39, 52 (1966) ("We do say, however, that known disadvantages in old devices which would naturally discourage the search for new inventions may be taken into account in determining obviousness."); *Depuy Spine, Inc. v. Medtronic Sofamor Danek, Inc.*, 567 F.3d 1314, 1324 (Fed. Cir. 2009).

244. *See, e.g.*, *Transocean Offshore Deepwater Drilling, Inc. v. Maersk Contractors USA, Inc.*, 617 F.3d 1296, 1304–05 (Fed. Cir. 2010); *Ortho-McNeil Pharm., Inc. v. Mylan Labs., Inc.*, 520 F.3d 1358, 1365 (Fed. Cir. 2008).

245. *See* Eisenberg, *Patents and the Progress of Science*, *supra* note 88, at 1052–53.

246. MERTON, *supra* note 85, at 277–78.

in industry, serving as a fail safe against ill-advised spending on projects that may be based on suspect data.

What differentiates this routine skepticism from the type of skepticism likely to lead to innovative delay is its duration and intensity. Routine skepticism is typically short-lived: a claim is made, peers scrutinize the data and request further back-up, additional experiments are carried out, and the claim is either dropped, published, or developed further into a marketable product. This type of skepticism is unlikely to discourage or delay research projects.

We should care about a second type of persistent, intense skepticism. It is this type of skepticism that was at play in *Adams* and in the case studies described in Part II.[247] Courts would also need to consider the existing relationships of trust and authority within the relevant community of practice. Opposition to a research program from a well-respected member of the "core-set" is more likely to delay innovation than opposition from an outsider or from a member of a different community of practice.

Finally, judgments based on relationships of trust and authority are most important in areas of high uncertainty, as is often the case in cutting-edge research.[248] That is, the more uncertain the outcome of a scientific project, the more the scientific community will rely on personal elements in addition to scientific data to assess whether a set of experimental results is convincing or whether a particular project is worth pursuing. This insight is relevant both for understanding how scientists themselves will interpret research proposals and experimental results, but also for how industry players (such as venture capitalists) will assess which scientific ventures to fund.[249] Thus, persistent skepticism from the "core-set" of experts in the field is an important secondary consideration, especially if the researcher or firm pursuing the invention is not part of such "core-set" and if the invention at issue is in a high-uncertainty research area.

247. *Adams*, 383 U.S. at 44 ("The . . . scientists who observed the demonstrations and who conducted further tests themselves did not believe [the invention] was workable. Almost a year later, in December 1942, Dr. George Vinal, an eminent government expert with the National Bureau of Standards, still expressed doubts.").

248. SHAPIN, *supra* note 93, at 18 (noting that in conditions of "radical uncertainty, judgment takes a specially personal form").

249. *Id.*

b. Unexpected results and innovative delay

The Court's emphasis in *KSR* on differentiating "predictable" from "unpredictable" or "unexpected" discoveries can be interpreted as encapsulating two related concerns. First, the Court sought to identify and reward those inventions that are more likely to be unique and thus less likely to be made simultaneously by multiple inventors. Second, the Court was concerned with the effects of a patent grant on follow-on innovators. The label "unexpected results" thus served as a heuristic to identify those unique inventions unlikely to be found in routine research and thus less likely to have a net negative effect on innovation.

A closer look at the types of discoveries that can be grouped under the category of "unexpected results," however, shows this heuristic to be flawed. While some unexpected results are indeed likely to represent unique inventions, others are likely to be discovered simultaneously by multiple researchers. In addition, experiments leading to unexpected results often inspire fruitful follow-on research. Thus, unexpected inventions—while often quite valuable contributions to existing knowledge—when patented are also often the most likely to stifle follow-on innovation by parties other than the inventor.

Considering "unexpected results" as a heuristic for nonobviousness can be justified in the case of "true accidents" and "byproducts." The availability of a patent for these two types of unexpected results may encourage researchers to take a detour from their main research interests, pay attention to those unexpected outcomes, and develop them into useful products. These two types of unexpected results are also more likely to represent unique discoveries. But when unexpected results are intrinsic to a research program, "unexpected results"—taken alone—ceases to be a good heuristic to identify unique inventions.

My analysis thus far, however, has not considered the role of patent races in innovation. Indeed, an objection to my analysis of "unexpected results" as serving as a proxy to identify unique inventions is that it does not take into account that simultaneous inventors may have been racing to obtain a patent. Under a patent racing model, patents stimulate earlier innovation by prodding inventors to work faster than they otherwise would.[250] And because different innovators will approach a similar problem from different angles, potentially leading to different discoveries, races are not necessarily a wasteful duplication of efforts.[251]

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250. *See, e.g.*, Duffy, *supra* note 9, at 444.

251. *See, e.g.*, LANDES & POSNER, *supra* note 21, at 301 (noting that research expenditures by the losers in a patent race may not be wasted because these expenditures will "generate information that losers may be able to use in other projects").

Even under a patent racing model, however, distinguishing between these types of unexpected results is important. Patent protection for what I have termed "true accidents" and "byproducts" extrinsic to a research program may not be justified under a racing model, because there cannot be a race to invent when invention is unintended.[252] But "anomalies" observed simultaneously by innovators that are engaged in a race are a different situation. Racing may push innovators to develop those observed unexpected results faster.

Unexpected results that arise as anomalies in the course of a research project—taken alone—are still not a good proxy for identifying those inventions that are the result of a patent race. Thus, the key question when faced with unexpected results intrinsic to a research program is not how unexpected or not the results were, but rather whether patent law was needed to stimulate that particular line of research or a race in that particular research program.

Finally, any theory of patent law needs to take into account the costs of patent protection to follow-on innovators, a second concern implicit in *KSR*.[253] Anomalies that contradict canonical knowledge in a particular discipline are likely to generate a flurry of follow-on innovation. Tinkering and experimentation by multiple *independent* parties with different backgrounds and approaches has historically played an important role in the investigation of anomalies.[254] In this context, broad patent rights granted to the first to win the race are likely to stifle research by parties other than the inventor. This is especially the case for patents on upstream technology or embryonic inventions, where independent investigation may be most socially beneficial.

A final justification for relying on "unexpected results" as a proxy for nonobviousness is that they signal high-risk projects with low probability of success that may be delayed absent the inducement of a patent.[255] But the label "unexpected results" signals risky projects *only* when researchers suppose *before* engaging in a research program that what they are seeking to find is unlikely. This would be the case, for

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252. *See, e.g.*, Lemley, *supra* note 58, at 759 (noting that a racing model "may not justify patent protection for those who invented without intending to do so"). The patent racing approach, however, neglects to consider important reasons to grant patents to "true accidents" and "byproducts." Patents may accelerate innovations based on both "true accidents" and "byproducts" even in the absence of a race by motivating the investigator to take a risk by deviating from her research agenda to focus on the unexpected observation.

253. *See supra* Part I.A.3.

254. *See, e.g.*, ROBERT FRIEDEL, A CULTURE OF IMPROVEMENT: TECHNOLOGY AND THE WESTERN MILLENNIUM 3 (2007).

255. *See, e.g.*, Abramowicz & Duffy, *supra* note 10, at 1671–72.

example, if separating the enantiomers at issue in *Sanofi-Synthelabo* would not have been undertaken—absent the availability of a patent—because it was expected that the separation would yield no substantial decrease in toxicity. Because "unexpected results" can arise in many different contexts of discovery, "teaching away" or "skepticism" are better proxies to capture high-risk projects with low expected probability of success.

CONCLUSION

In its landmark decision, *KSR v. Teleflex*, the United States Supreme Court emphasized the importance of a contextual inquiry into patentability that takes into account "the circumstances surrounding the origin of the subject matter sought to be patented."[256] In seeking to define these circumstances, current patent law scholarship focuses primarily on the background economic forces that drive innovation (the "competitive baseline"). I have argued that a full description of the context of innovation also requires understanding the social determinants of innovation, or what I have termed the "social baseline." Analyzing and applying insights from historical and sociological studies of science and technology about how institutional norms and practices shape the course, pace, and content of innovation, this Article takes the first steps in outlining this social baseline.

To demonstrate the fruitfulness of this approach, my analysis centered on the obviousness doctrine. I focused on three types of social phenomena that influence the direction, content, and rate of innovation. First, a sociological view of innovation emphasizes the central role of communities of practice, which develop a set of vested interests in particular approaches, techniques, and ways of framing research questions. Such a view allows us to understand innovation as both stimulated and hindered by the interrelated processes of specialization and intellectual migration. Specialization has an inflationary effect, stimulating members of communities of practice to apply their research tools and framing devices to an expanding array of problems. But specialization also hinders innovation by creating a set of vested interests that can resist new approaches from outside the specialty. Second, within each specialty, a core-set of practitioners tends to define what constitutes legitimate lines of research or credible experimental results. Thus, opposition or skepticism from such a core-set can be an important contributor to innovative delay. Third, I examined the role of unexpected

256. *KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398, 399 (2007) (quoting *Graham v. John Deere Co.*, 383 U.S. 1, 17–18 (1966)).

discoveries on the pace and content of innovation. I argued for a more fine-grained analysis of historical cases, which reveals three distinct types of "unexpected inventions." Importantly, one of these subtypes (anomalous observations intrinsic to a research program) is likely to spark swift follow-on innovation, thus suggesting a context in which broad patent rights may impose particularly high social costs. This more nuanced understanding of the social context of innovation counsels a reorientation of the current obviousness inquiry to focus on incentivizing field-crossing inventions. This is particularly important when vested interests are likely to delay or block fruitful intersections between communities of practice, and when interdisciplinary team approaches to problem solving are uncommon.

Patent law is one of the primary policy tools through which society provides incentives for technological innovation. But, as Francis Bacon remarked, "knowledge and human power are synonymous, since the ignorance of the cause frustrates the effect."[257] Designing patent law to effectively foster innovation requires knowing the background mental, social, and economic forces, the causes that influence inventive activity.

257. FRANCIS BACON, NOVUM ORGANUM 315 (Colonial Press rev. ed. 1900).