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NON-LINEAR INNOVATION

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Contemporary intellectual property theory concentrates on the cumulative and incremental nature of innovation and creation. A prevalent image depicts authors and inventors as "standing on the shoulders of giants." This article focuses on a different type of innovation that has been largely overlooked by intellectual property theory and doctrine: innovation in the domains of science and art that breaks with convention, disputes existing paradigms, and "steps off" giants' shoulders. I term it "non-linear innovation".

Drawing on multidisciplinary research ranging from the history of science, through network analysis of radical inventions, to studies of creativity, this article illuminates an embedded socio-cultural preference for incremental and linear novelty over paradigm-changing innovation. It then inquires whether intellectual property doctrine reflects this bias and whether the intellectual property regime can better foster non-linear innovation. The examination yields a series of counterintuitive recommendations concerning numerous patent and copyright law doctrines. More broadly, the analysis indicates that neither the "shoulders of giants" metaphor nor the opposite image of the "lone genius" adequately capture the dynamics of non-linear innovation. It further suggests that expanding intellectual property's narrative of progress to accommodate non-linear innovation, alongside cumulative innovation, could significantly contribute to the ecosystem of innovation and creation.

La théorie de propriété intellectuelle contemporaine se concentre sur le caractère cumulatif et incrémental de l'innovation et de la création. Les auteurs et inventeurs sont dépeints « debout sur les épaules de géants ». Cet article se penche sur un type d'innovation négligé par la théorie et la doctrine de la propriété intellectuelle : l'innovation, en science et en art, qui déroge aux conventions, remet en question les paradigmes dominants et descend des épaules des géants. L'auteure la qualifie d' « innovation non-linéaire ».

À partir de travaux multidisciplinaires allant de l'histoire des sciences aux études de la créativité, en passant par l'analyse de réseaux, l'article met en lumière un biais socio-culturel favorisant une conception linéaire du progrès. Il cherche ensuite à savoir si la doctrine en propriété intellectuelle reflète ce biais, et si la propriété intellectuelle pourrait stimuler davantage l'innovation non-linéaire. Une série de recommandations contre-intuitives quant aux doctrines du droit des brevets et des droits d'auteurs en découle. De façon générale, cette analyse indique que ni la métaphore des « épaules de géants » ni celle du « génie solitaire » ne saisissent adéquatement la dynamique de l'innovation non-linéaire. Selon notre analyse, étendre le concept de progrès à l'innovation non-linéaire, sans délaisser l'innovation cumulative, pourrait contribuer significativement à l'écosystème d'innovation et de création.

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Introduction

The year was 1982 when Dan Shechtman, a junior scientist in the field of materials science, discovered a quasi-periodic crystal.[1] The discovery was not merely novel; it stood in sharp contrast to the then-prevalent scientific belief that explicitly denied the existence of quasicrystals. It went against the textbooks in the field of crystallography and contested the position of the prominent scientists of the period.[2] Shechtman decided to publish his findings. In doing so, he was stepping off the shoulders of giants. And the giants responded. Shechtman was sent to re-read the textbooks and was later asked to leave his research team.[3] Linus Pauling, a two-time Nobel Laureate, famously declared that "[t]here is no such thing as quasicrystals, only quasi-scientists."[4] For many years, Shechtman was the subject of contempt and ridicule. In 2011, he won the Nobel Prize for his discovery.[5]

This article uses the story of Dan Shechtman as a starting point for exploring a broader phenomenon of non-linear innovation and its interrelations with intellectual property law. Intellectual property scholarship in recent decades has concentrated on the cumulative and incremental nature of creativity and innovation.[6] That literature frequently describes au-

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1 See Istvan Hargittai, *Drive and Curiosity: What Fuels the Passion for Science* (Amherst, NY: Prometheus Books, 2011) at 161–62. In contemporary crystallography a "quasi-periodic" crystal describes a structure that is ordered but not periodic (see Gerald D Mahan, "Quasicrystal" in *Encyclopœdia Brittanica*, online: <www.britannica.com/science/quasicrystal>).

2 See Hargittai, *supra* note 1 at 162. Shechtman himself used the following image to describe the contradiction between his discovery and the prevalent scientific convention: "Imagine that you see a dinosaur in the desert. Everyone tells you 'this is not possible, it's an environmental sculpture.' ... I knew that, according to literature, my discovery was impossible and tried to find a way to explain it under the prevalent paradigm" (interview with author, July 2014).

3 See Shechtman, *supra* note 2.

4 Philip Ball, "Impossible Chemistry: Crystal Paradox", *New Scientist* 2848 (18 January 2012), online: <www.newscientist.com/article/mg21328481-400-impossible-chemistry-crystal-paradox/>; Shechtman, *supra* note 2.

5 See Sven Lidin, "Award Ceremony Speech", *The Nobel Foundation* (10 December 2011), online: <www.nobelprize.org/nobel_prizes/chemistry/laureates/2011/presentation-speech.html>.

6 See e.g. Jessica Litman, "The Public Domain" (1990) 39:4 Emory LJ 965 at 965–67 (stressing that all creators base their creations on previous materials); Suzanne Scotchmer, "Standing on the Shoulders of Giants: Cumulative Research and the Patent Law" (1991) 5:1 J Economic Perspectives 29 at 29 (highlighting the cumulative nature of scientific and technological research); Graham M Dutfield & Uma Suthersanen, "The Innovation Dilemma: Intellectual Property and the Historical Legacy of Cumulative Creativity" (2004) 4 IPQ 379 at 379 (emphasizing the cumulative nature of most inno-

thors and inventors as "standing on the shoulders of giants"—a phrase often attributed to Isaac Newton.[7] This perception portrays progress as a linear and incremental process of puzzle-solving where each author and inventor builds upon the works and achievements of her predecessors. Indeed, the dwarfs-and-giants aphorism has become a most powerful meme not only in intellectual property discourse, but also in general culture.[8]

This prism, while undoubtedly valuable for shaping intellectual property policy, does not provide a complete and accurate picture of innovation and progress. Whereas most works and inventions *are* indeed linear and cumulative, there is an additional type of innovation that occurs in both cultural and scientific spheres: innovation that is not concerned with linear and incremental improvements, but with dissent and discontinuity—innovation that breaks up with convention, identifies misconceptions, or disputes existing paradigms. Such innovation "steps off" the shoulders of giants rather than stands on their shoulders. I term this type of innovation "non-linear innovation".

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vations in the industrial and cultural spheres); Jeanne C Fromer, "Patent Disclosure" (2009) 94:2 Iowa L Rev 539 at 541 [Fromer, "Patent Disclosure"] (describing patent law as premised on the notion of cumulative development of science and technology); Mark P McKenna & Katherine J Strandburg, "Progress and Competition in Design" (2013) 17:1 Stan Tech L Rev 1 at 46–50 (arguing that a theory of cumulative progress should guide the protection of designs). For similar insights in economic and business management literature, see e.g. Fiona Murray & Siobhán O'Mahony, "Exploring the Foundations of Cumulative Innovation: Implications for Organization Science" (2007) 18:6 Organization Science 1006 at 1006 (highlighting the growing importance of cumulative innovation). See also the discussion in Part IV, below.

7 This attribution is inaccurate. Although Newton used the aphorism in his correspondence with Robert Hooke in 1676, it can be traced back to philosopher Bernard de Chartres in the twelfth century. For a fascinating account of the origins and diffusion of the giants and dwarfs aphorism, see Robert K Merton, *On the Shoulders of Giants: A Shandean Postscript* (New York: Free Press, 1965). See also HW Turnbull, ed, *The Correspondence of Isaac Newton*, vol 1 (Cambridge: Cambridge University Press, 1959) at 416.

8 Several illustrations of the use of the phrase are found in blockbuster films. See e.g. *Jurassic Park* (Universal City: Universal Pictures, 1993), script online: <sfy.ru/?script=jurassic_park>; *The Social Network* (Los Angeles: Columbia Pictures, 2010), script online: <flash.sonypictures.com/video/movies/thesocialnetwork/awards/thesocialnetwork_screenplay.pdf>; "Born Again", episode of *The X Files* (Los Angeles: 20th Century Fox Studios, 29 April 1994), script online: <www.users.globalnet.co.uk/~gjm5xx/transcrp/scrp122.htm>. The phrase is also the title for the fourth studio album of the rock band Oasis (Oasis, *Standing on the Shoulder of Giants* (Big Brother Recordings, 2000), online: <www.oasisinet.com/#!/music/album/standing-on-the-shoulder-of-giants>); the slogan for Google Scholar (Google Scholar, online: <scholar.google.ca>); and appears in the lyrics of the song "King of Birds" included in REM's fifth studio album (REM, *Document* (Capitol, 1987), lyrics online: <www.azlyrics.com/lyrics/rem/kingofbirds.html>).

This article demonstrates that the notion of non-linear innovation is well recognized by various disciplines including history of science,[9] economics,[10] and socio-cultural studies of creativity.[11] Yet, despite its significance, non-linear innovation as a phenomenon has largely been overlooked by intellectual property theory. Rather, the prevailing image of innovation in contemporary intellectual property literature portrays a narrative of linear, cumulative, "shoulders of giants" progress.[12] While a handful of studies in recent years importantly highlighted several aspects of the interface between paradigm shifts and patent law,[13] there is still no systematic exploration of non-linear innovation as a socio-cultural phenomenon affecting all fields of innovation and creativity. Moreover, the implications of non-linear innovation for intellectual property's narrative of progress, and for numerous doctrines in patent and copyright law, are largely unexplored. This article seeks to fill in this void and shed light on a rather neglected area of the innovation system. Drawing on multidisciplinary research, it conceptualizes non-linear innovation and offers an analytical framework for exploring its interrelations with intellectual property theory and doctrine. The discussion illuminates common patterns in seemingly disparate areas of innovation, namely technological in-

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9 See e.g. Ian Hacking, "Introductory Essay" in Thomas S Kuhn, *The Structure of Scientific Revolutions*, 4th ed (Chicago: University of Chicago Press, 2012) vii. See also the discussion in Part I, below.

10 See e.g. Manuel Trajtenberg, "A Penny for Your Quotes: Patent Citations and the Value of Innovations" (1990) 21:1 RAND J Econ 172; Kristina B Dahlin & Dean M Behrens, "When Is an Invention Really Radical? Defining and Measuring Technological Radicalness" (2005) 34:5 Research Policy 717 at 717–24; Wilfred Schoenmakers & Geert Duysters, "The Technological Origins of Radical Inventions" (2010) 39:8 Research Policy 1051 at 1052–53. See also Clayton M Christensen, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail* (Boston: Harvard Business School Press, 1997) at xv (for the notion of "disruptive technologies" in business management literature). See also the discussion in Part I, below.

11 See e.g. R Keith Sawyer, *Explaining Creativity: The Science of Human Innovation*, 2nd ed (New York: Oxford University Press, 2012) at 89–93. See also the discussion in Part I, below.

12 See the discussion in Part IV, below.

13 See Peter Lee, "Patents, Paradigm Shifts, and Progress in Biomedical Science" (2004) 114:3 Yale LJ 659 (maintaining that the patent regime can play a role in inducing paradigm shifts and further advocating the strict enforcement of patents over research tools); Sean B Seymore, "Atypical Inventions" (2011) 86:5 Notre Dame L Rev 2057 at 2078 [Seymore, "Atypical Inventions"] (observing that inventions that challenge well-established scientific principles may be deemed unpatentable due to lack of usefulness); Laura G Pedraza-Fariña, "Patent Law and the Sociology of Innovation" (2013) 2013:3 Wis L Rev 813 (observing that the design of patent law should consider the sociological context of innovation and highlighting the difficulty of deviating from canonical conventions). For further discussion of these works, see Part III, below.

ventions and artistic creativity, and provides a more holistic account of our innovation ecosystem.

The analysis in this article reveals that the narrative of strictly linear progress is prevalent in broad social contexts. It further highlights a strong socio-cultural preference for incremental novelty over paradigm-changing innovations and a parallel difficulty to appreciate and absorb works and inventions that break with convention.[14] This "non-linear innovation bias" creates various obstacles for innovators wishing to step off the shoulders of giants and produces significant social costs. Based on these insights, I argue that intellectual property law, entrusted with the task of promoting progress, cannot remain oblivious to non-linear innovation. Rather, intellectual property theory should actively seek ways to facilitate it and explicitly include non-linear innovation in its narrative of progress.

This article then takes a closer look at several prominent traits of non-linear innovations and examines their implications for various intellectual property doctrines. Such exploration yields three principal insights.

First, counterintuitively, fostering non-linear innovation does *not* mandate a policy of enclosure, but rather supports policies of disclosure and access to intellectual property-protected subject matter. More specifically, a system that seeks to promote non-linear innovation should be particularly concerned with providing potential innovators with access to errors, misconceptions, and additional negative knowledge.[15] Against this insight, this article examines several access-facilitating mechanisms in copyright and patent law and proposes adjustments to these tools that would facilitate non-linear types of innovation.

Second, the analysis highlights the relatively slow diffusion of non-linear innovations in comparison to incremental innovations in professional and social networks. It then explores the implications of this trait for intellectual property doctrines that are time-sensitive, specifically copyright's doctrine of *droit de suite* and patent law's doctrine of commercial success.[16]

Third, relying on recent network analyses of radical inventions in economic studies, this article suggests that it is possible to identify non-linear innovations in technological fields in a more accurate manner. It further explores how the insights emerging from network analyses can be incorporated into patent law doctrines—primarily the nonobviousness

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14 See Part II, below.

15 See Part III.B., below.

16 See Part III.C., below.

threshold and the doctrine of pioneering inventions—so as to better capture non-linear innovations.[17]

Finally, beyond specific doctrinal recommendations, the analysis demonstrates that accommodating non-linear innovation as part of intellectual property's theory of progress is culturally significant and could itself contribute to mitigating the non-linear innovation bias.[18]

One important point should be stressed before commencing our exploration. Acknowledging that some innovation is non-linear does *not* necessitate rejecting the narrative of cumulative innovation. The incremental character of most works and inventions is undisputed and should continue to play an important role in shaping intellectual property policy. Nor do I argue that non-linear innovations are created in a vacuum without any reliance on preceding works and inventions. In fact, one of this article's principal insights is that the relations between linear and non-linear innovation are far from dichotomous and intellectual property doctrines that serve to promote the former may also support the latter.[19] My purpose, then, is not to undermine cumulative innovation, but rather to draw a more accurate and complete picture of innovation and creation as a basis for intellectual property policy.

The discussion proceeds as follows. Part I introduces the notion of non-linear innovation and demonstrates its prevalence in scientific, cultural, and technological spheres. Part II describes the non-linear innovation bias and its multiple origins. Part III examines the implications of the preceding analysis for intellectual property law and puts forth a series of proposals concerning various patent and copyright law doctrines. Part IV then looks beyond intellectual property doctrine to the broader interface of law and culture and highlights the significance of accommodating non-linear innovations in intellectual property theory.

I. Conceptualizing Non-Linear Innovation

Studies in the history of science and in the sociology of creativity have long recognized that innovation is not always gradual and incremental. The most renowned work on this topic is the seminal treatise of Thomas Kuhn: *The Structure of Scientific Revolutions*.[20] *The Structure* describes science as progressing through non-linear revolutions, which Kuhn fa-

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17 See Part III.D., below.

18 See Part IV, below.

19 See the discussion in Part III, below. See also *infra* notes 116–22 and accompanying text.

20 Kuhn, *supra* note 9.

mously labelled "paradigm shifts".[21] Paradigm shifts depart from previous scientific conceptions, identify errors in preceding theories, and introduce new frames of thought that change the language of the relevant field.[22] After a new paradigm gains acceptance in the scientific community, it is typically followed by periods of "normal science"—research under the prevailing paradigm that builds on its basic premises and attempts to solve the puzzles within its framework.[23] This type of science is truly incremental and cumulative. Yet, inevitably, after a period of time, a field witnesses the emergence of a new paradigm that is somewhat incommensurable with the previous one and the process repeats itself.[24]

The notion that progress in not always linear is not confined to Kuhn. Prominent writings in various disciplines echo similar perceptions and highlight the significance of inconsistencies, discontinuity, and refutations—or, in other words, of stepping off giants' shoulders—for human progress. Centuries before Kuhn, Francis Bacon famously observed that "truth will sooner come out from error than from confusion."[25] Karl Popper's work in the philosophy of science similarly highlighted the importance of criticism, refutation, and falsification for scientific progress.[26] In economics, Joseph Schumpeter coined the phrase "creative destruction" to describe economic progress that destroys existing structures in the process of creating new ones,[27] while the more recent concept of "disruptive innovation" in the field of business management describes innovations that disrupt existing markets and expresses a similar idea of discontinuity.[28]

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21 *Ibid* at 66–68.

22 See *ibid* at 66–68, 200.

23 See *ibid* at 36–42.

24 See *ibid* at 149.

25 James Spedding, Robert Leslie Ellis & Douglas Denon Heath, eds, *The Works of Francis Bacon*, vol 8 (Boston: Taggard & Thompson, 1864) at 210.

26 See Karl R Popper, *The Logic of Scientific Discovery* (London: Routledge Classics, 2002) at 10; Karl R Popper, *Conjectures and Refutations: The Growth of Scientific Knowledge* (London: Routledge & Kegan Paul, 2002) at xi [Popper, *Conjectures*].

27 Joseph A Schumpeter, *Capitalism, Socialism, and Democracy* (New York: Harper & Brothers, 1950) at 83.

28 See Clayton M Christensen, Michael E Raynor & Rory McDonald, "What Is Disruptive Innovation?", *Harvard Business Review* (December 2015), online: <hbr.org/archive-toc/BR1512?cm_sp=Article-_-Links-_-Magazine%20Issue#>. See also Christensen, *supra* note 10 at xiv–xv. Notably, however, the original meaning ascribed by Christensen to the term "disruptive innovation" focuses on the disruptive impact of the innovation on the relevant market and not on its technological attributes, which can be either radical or incremental.

Examining the progress of science and the arts through this lens yields a multitude of examples of discontinuous dynamics: Dan Shechtman was stepping off the shoulders of Linus Pauling, the biochemistry giant who rejected quasi-crystals;[29] Einstein was stepping off the shoulders of Newton with his theory of relativity that is incompatible with the Newtonian view of space;[30] and interestingly, Newton himself—despite the famous quote about standing on giants' shoulders—actually stepped off the shoulders of several giants, including Galileo whose view of gravity was inconsistent with Newton's *Principia*.[31]

Progress in the life sciences displays similar patterns. The germ theory of disease, introduced in the middle of the nineteenth century, maintained that germs exist and constitute a source of infectious diseases.[32] This notion—which later led to the development of sterilization technologies, paved the way for antibiotics, and revolutionized medicine[33]—departed from the then-prevalent paradigm that attributed disease to bad air emanating from rotting organic matter.[34] Likewise, the Mendelian theory of genetic inheritance, first announced in 1865, introduced the concept of separate inheritance of different traits that deeply influenced modern genetics. Yet, at the time of its introduction, this concept was inconsistent with the then-predominant paradigm of joint and total inheritance of biological characteristics.[35] Theories about the causes of cancer have similarly gone through several paradigm shifts over the years.[36]

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29 See *supra* notes 1–5 and accompanying text.

30 See Kuhn, *supra* note 9 at 72–73 (explaining that Newton's theory considered space and time as absolute).

31 See *ibid* at 27–28 (outlining that while Galileo believed that free-falling bodies contain a constant of acceleration (g = constant), Newton's paradigm presumed that "g" is not constant but depends on the mass of the attracting body and the distance from the centre of that mass).

32 See generally Judith Herbst, *Germ Theory* (Minneapolis: Twenty-First Century Books, 2008) (describing the development of the theory including its earlier origins in the sixteenth century). See also Bernard Barber, "Resistance by Scientists to Scientific Discovery" (1961) 134:3479 Science at 597–98.

33 See Lois N Magner, "The Germ Theory of Disease" in K Lee Lerner & Brenda Wilmoth Lerner, eds, *Scientific Thought in Context*, vol 1 (Detroit: Gale, 2009), online: <www.omnilogos.com/2015/03/the-germ-theory-of-disease.html>.

34 See Herbst, *supra* note 32 at 8; Barber, *supra* note 32 at 597.

35 See Barber, *supra* note 32 at 598.

36 In ancient times, the origins of cancer were attributed to immoral behaviour, depression, or celibacy. The diffusion of the theory of genetic inheritance by the end of the nineteenth century resulted in the rise of the hereditary paradigm, attributing cancer to genetic causes. The solely-genetic paradigm was deeply disrupted with the notion that viruses caused some cancers, which was first explored during the 1930s and 1940s.

The distinction between non-linear shifts and linear cumulative work is not unique to the sciences. Studies of creativity in cultural and artistic fields echo parallel concepts. This scholarship distinguishes between "problem finding" and "problem solving" creativity.[37] The phrase "problem finding" should not be taken too literally as merely highlighting issues that require solutions.[38] Rather, much like the Kuhnian notion of paradigm shifts, problem finding creativity involves the creation, discovery, framing, and formulation of problems by the creative individual in a manner that was not done by her predecessors.[39] It includes, for example, the creation of new artistic styles or the consideration of existing topics and questions from new angles.[40] Problem solving creativity, on the other hand, works within the boundaries of predefined conventions, genres, or frames,[41] and is thus analogous to the concept of normal science.

Despite severe initial objections, the existence of tumour viruses is today widely acknowledged as a significant cause of cancers in humans. See Daniel J Kevles, "Pursuing the Unpopular: A History of Courage, Viruses, and Cancer" in Robert B Silvers, ed, *Hidden Histories of Science* (New York: New York Review of Books, 1995) at 69, 71 (describing paradigm shifts in cancer research); Pedraza-Fariña, *supra* note 13 at 848–49 (discussing the negative reaction of the scientific community to the pioneering works concerning tumour viruses); Harald zur Hausen, "Viruses in Human Cancers" (1991) 254:5035 Science 1167 at 1168 (describing the recognition of viruses as an important risk factor for cancer in humans).

37 See Sawyer, *supra* note 11 at 90–93 (discussing this distinction in psychological literature); JW Getzels, "Problem Finding: A Theoretical Note" (1979) 3:2 Cognitive Science 167; Jacob W Getzels & Mihaly Csikszentmihalyi, *The Creative Vision: A Longitudinal Study of Problem Finding in Art* (New York: John Wiley & Sons, 1976) at 77–83. For a recent discussion of the concepts of problem finding and problem solving in intellectual property scholarship, see Jeanne C Fromer, "A Psychology of Intellectual Property" (2010) 104:4 Nw UL Rev 1441 at 1444–45 [Fromer, "Psychology"] (arguing that the distinction has interpretive power and can explain various intellectual property doctrines).

38 *Cf* Getzels, *supra* note 37 at 167 ("[n]eed a problem be *found*? Is not the world already teeming with problems and dilemmas?" [emphasis in original]).

39 See *ibid* at 169. Getzels & Csikszentmihalyi argue that "the main elements of creativity ... are the formulation of a problem ... " (*supra* note 37 at 79) and maintain that problem finding "may be a more important aspect of creative thinking ... than is solving a problem once it has been found and formulated" (*ibid* at 82).

40 See Sawyer, *supra* note 11 at 91; Getzels & Csikszentmihalyi, *supra* note 37 at 77, 82–83 (describing the formulation of a problem as a "crucial phase" in the artistic process); Margaret A Boden, "What is Creativity?" in Margaret A Boden, ed, *Dimensions of Creativity* (Cambridge, Mass: MIT Press, 1994) 75 at 79 (discussing artistic creativity that forms new "conceptual spaces"). For similar observations about creativity in science, see Albert Einstein & Leopold Infeld, *The Evolution of Physics: The Growth of Ideas from Early Concepts to Relativity and Quanta* (New York: Simon and Schuster, 1961) at 92 (observing that "[t]he formulation of a problem is often more essential than its solution").

41 See e.g. Getzels & Csikszentmihalyi, *supra* note 37 at 81; Sawyer, *supra* note 11 at 93.

This distinction implies that creativity in the arts, like creativity in science, is not strictly linear.[42] Some works and projects modify the rules of grammar of a relevant artistic field and open the door to the subsequent formulation of expressions that could not be previously articulated. And, like the history of science, the history of art, literature, and music is composed of periods of tradition disrupted by non-cumulative breaks in style or artistic language.[43] The rise of Cubism, for example, revolutionized European painting in the early twentieth century.[44] Pioneered by Brauqe and Picasso, Cubism departed from the notion of art as an imitation of nature that dominated Europe since Renaissance times and offered a new depiction of space, mass, time, and volume.[45] Similarly, the genre of installation art that evolved in the second half of the twentieth century challenged the dominance of painting and offered a new paradigm for experiencing art.[46] Likewise, the first musical works in the rap genre introduced in North America during the late 1970s were "a radical innovation" and stood in sharp contrast to the notion of melody that dominated American music at the time.[47] In the field of movie making, too, George Lucas' *Star Wars*, released in 1977, launched a new paradigm by giving primary importance to the film's visual effects.[48]

As the above discussion demonstrates, not all innovation is a "shoulders of giants" type of innovation. Rather, non-linear dynamics characterize the progress of science and arts today as they did in earlier times. Focusing on these dynamics further sheds light on the value of non-linear innovation for scientific and cultural progress. By creating novel prisms for exploring questions in science and the arts, non-linear innovations in-

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42 See Getzels, *supra* note 37 at 168 (emphasizing that problem finding creativity exists in science, in the arts, and in all fields of learning).

43 See Kuhn, *supra* note 9 at 207 (acknowledging that revolutionary shifts occur in many areas, including arts, literature, and music); Sawyer, *supra* note 11 at 6–7 (describing "bursts" and transitions in the fields of music, choreography, and film).

44 See Shannon Robinson, *Cubism: Movements in Art* (Mankato, Minn: Creative Education, 2006) at 8; David Cottington, *Cubism and Its Histories* (Manchester: Manchester University Press, 2004) at 4.

45 See Robinson, *supra* note 44 at 15; Cottington, *supra* note 44 at 35–36, 203–08, 219.

46 See Julie H Reiss, *From Margin to Center: The Spaces of Installation Art* (Cambridge, Mass: MIT Press, 1999) at 14, 64 (explaining that installation art introduced a shift from art works that are isolated to art that is experienced in a particular context); Sawyer, *supra* note 11 at 6.

47 See Everett M Rogers, *Diffusion of Innovations*, 5th ed (New York: Free Press, 2003) at 220–21.

48 See Sawyer, *supra* note 11 at 313–14.

troduce new rules of grammar and create new conceptual spaces.[49] They generate a switch in the "visual gestalt" of their field, allow us to see things in a different light, and formulate questions, possibilities, and expressions that we could not formulate previously.[50] As Albert Einstein and Leopold Infeld astutely observed, "[t]o raise new questions, new possibilities, to regard old problems from a new angle, requires creative imagination and marks real advance in science."[51]

Due to these attributes, non-linear innovations pave the way for many subsequent works and follow-on inventions and may completely alter scientific and technological domains.[52] For example, the paradigm shift introduced by *Star Wars* in 1977 marked a fundamental change in the way movies are made which has been followed by multiple films since.[53] The first works in the genre of installation art paved the way for many successive works in this genre.[54] Similarly, the germ theory of disease led to the development of sterilization technologies and antibiotic drugs and marked the birth of modern surgery.[55]

Yet stepping off the shoulders of giants is not easy. The following Part focuses on the difficulties faced by non-linear innovators and demon-

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49 See Boden, *supra* note 40 at 79 (describing creativity in the arts in terms of new "conceptual spaces" and exploring the language analogy).

50 See Hacking, *supra* note 9 at xxix (observing that, following a paradigm shift, scientists in the field "may view the world differently, have a different feeling for how it works, notice different phenomena, be puzzled by new difficulties, and interact with it in new ways").

51 Einstein & Infeld, *supra* note 40 at 92.

52 See e.g. Gautam Ahuja & Curba Morris Lampert, "Entrepreneurship in the Large Corporation: A Longitudinal Study of How Established Firms Create Breakthrough Inventions" (2001) 22:6–7 Strategic Management J 521 at 523 (indicating that foundational inventions serve as the basis for many subsequent technological inventions); Ibo van de Poel, "The Transformation of Technological Regimes" (2003) 32 Research Policy 49 at 49 (observing that "successful radical innovations ... can transform existing patterns of technological regimes, and thus have lasting effects on technical development"); Sam Arts & Reinhilde Veugelers, "The Technological Origins and Novelty of Breakthrough Inventions" (2012) Ku Leuven Faculty of Economics and Business Working Paper, online: <lirias.kuleuven.be/bitstream/123456789/377027/1/MSI_1302.pdf> (referring to "breakthrough inventions" that serve as the basis for many subsequent technological inventions); David S Abrams, Ufuk Akcigit & Jillian Popadak, "Patent Value and Citations: Creative Destruction or Strategic Disruption?" (2013) Institute for Economics Research Paper No 13-23 at 9, online: <ssrn.com/abstract=2351809> (maintaining that the "more novel innovations generate larger spillovers for subsequent innovations").

53 See Sawyer, *supra* note 11 at 313–14.

54 See Reiss, *supra* note 46 at xv.

55 See Wilfred Trotter, "The Hunterian Oration: The Commemoration of Great Men" (1932) British Medical J 317 at 318.

strates that the story of Dan Shechtman is illustrative of a much broader phenomenon: the non-linear innovation bias.

II. The Non-Linear Innovation Bias

Despite the high degree of novelty and the social value of their works, creators and inventors who step off the shoulders of giants often face opposition, objection, and rejection.[56] Indeed, some degree of skepticism is understandable, and sometimes necessary; caution and careful scrutiny are the foundations of scientific thought and are essential for scientific progress.[57] Yet, when non-linear innovations are concerned, the objection they encounter often exceeds healthy skepticism. Rather, it is strongly related to challenging prevalent conventions.[58]

Hence, the history of science is fraught with examples of non-linear innovations that were greeted not only with skepticism, but also with hostility and ridicule. Copernicus was called "mad" because he claimed that the earth moved, and a century after his death only a handful of scientists accepted his theory.[59] Newton was blamed that his theory "would return science to the Dark Ages," and it took the *Principia* more than half a century to gain acceptance in Europe.[60] The discovery of x-rays by Roentgen in 1895 was pronounced "an elaborate hoax,"[61] while almost a century later Dan Shechtman was named a "quasi-scientist" by the most prominent biochemist of the twentieth century.[62]

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56 See *ibid* at 319 ("discoverers of new truths always find their ideas resisted").

57 See e.g. Barber, *supra* note 32 at 599 (observing that "shared idea-systems" and "patterns of social interactions among scientists ... [that] become sources of resistance to discovery" are "elements that, on the whole, probably serve to advance science"). In a conversation with Dan Shechtman, he similarly observed that scientific scrutiny of novel paradigms is inevitable (see Shechtman, *supra* note 2).

58 See Trotter, *supra* note 55 at 320 (maintaining that the resistance to new ideas cannot be explained by mere scientific skepticism); Lidin, *supra* note 5 (indicating that "[t]he disbelief that met Dan Shechtman was appropriate and healthy" but "[t]he ridicule he suffered was ... deeply unfair"). See also *infra* notes 59–79 and accompanying text.

59 See Kuhn, *supra* note 9 at 148–50; Kathryn Schulz, *Being Wrong: Adventures in the Margin of Error* (London: Portobello Books, 2010) at 127 (describing the fierce objection to the Copernican revolution).

60 See Kuhn, *supra* note 9 at 150, 162.

61 *Ibid* at 59.

62 Ball, *supra* note 4. See also *supra* notes 1–5 and accompanying text.

In the life sciences, the Mendelian theory of genetics encountered ardent rejection from its announcement in 1865 until after Mendel's death.[63] The botany giant of the period, Carl von Nägeli, was particularly resentful, displaying a "supercilious" attitude not only toward the genetic theory but also toward Mendel himself.[64] The introduction of the germ theory of disease was likewise greeted with "violent resistance" on the part of the medical profession.[65]

Similarly, when Max Planck advocated that the conduction of heat was fundamentally different from a purely mechanical process, he faced such fierce objection from the prominent physicists of the period that he later recounted in his autobiography: "All my sound arguments fell on deaf ears. It was simply impossible to be heard against the authority of men like Ostwald, Helm and Mach."[66] Although Planck's paradigm eventually prevailed, he regarded this rejection as representative of his entire experience as a scientist[67] and wistfully concluded: "[a] new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die."[68] Interestingly, a century earlier, Charles Darwin expressed similar sentiments in his work *On the Origin of Species*.[69]

The domain of art and culture displays a similar bias. Cutting-edge works that break with generic conventions or dispute prevalent artistic paradigms often meet with skepticism on the part of general audiences and connoisseurs when trying to enter the market.[70] The early Cubist

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63 See Barber, *supra* note 32 at 598. For the non-linear character of the Mendelian paradigm, see *supra* note 35 and accompanying text.

64 Barber, *supra* note 32 at 600 (describing how von Nägeli and additional authorities looked down at Mendel and treated him as inferior).

65 *Ibid* at 601. For the paradigm shift introduced by the germ theory, see *supra* notes 2–5 and accompanying text.

66 Max Planck, *Scientific Autobiography and Other Papers*, translated by Frank Gaynor (New York: Philosophical Library, 1949) at 30.

67 See *ibid* (describing this pattern as "one of the most painful experiences in my entire scientific life").

68 *Ibid* at 33–34.

69 Charles Darwin, *On The Origin of Species* (London: Ward Lock & Co, 1910) at 370 ("[a]lthough I am fully convinced of the truth of the views ... I by no means expect to convince experienced naturalists whose minds are stocked with a multitude of facts all viewed, during a long course of years, from a point of view directly opposite to mine. ... [B]ut I look with confidence to the future, to young and rising naturalists, who will be able to view both sides of the question with impartiality").

70 See Sawyer, *supra* note 11 at 218–19 (discussing artists' difficulties to deviate from audiences' expectations and present cutting-edge works); Fromer, "Psychology", *supra*

paintings, for example, were greeted with abusive rhetoric describing them as "'monstrous', 'insane', 'horrific', 'infantile', and 'primitive'" and "the work of 'impotent dilettantes.'"[71] The objection was so fierce that in 1912 the issue of Cubism even reached the French Parliament.[72] Years later, the first displays of installation art in galleries received a critical response that was "both slight and slighting."[73] George Lucas received a cold shoulder when he first introduced *Star Wars* in private screenings where both critics and friends predicted its failure.[74] Likewise, the early works in the rap genre were not only rejected by the music establishment but also faced a radio embargo.[75]

The evidence regarding the bias against non-linear innovation is not merely anecdotal. Recent empirical findings substantially support it. One such study tested the effect of novelty on grant allocations in the biomedical field.[76] The findings indicate that higher levels of novelty have a significant *negative* impact on the rating of grant applications; novel research projects that deviate from existing research paradigms receive less favourable evaluations than projects confined to the boundaries of "normal science".[77] In other words, even within academic settings, it is easier to obtain funding for cumulative research than for research introducing new paradigms. Another recent work analyzed 17.9 million research papers from various disciplines and measured their impact and their level of novelty.[78] The findings indicate, again, that the papers with the highest nov-

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note 37 at 1479–81 (arguing, based on psychological research, that too much novelty in artistic works increases the risk of failure).

71 Cottington, *supra* note 44 at 26.

72 See *ibid* at 3 (quoting Deputy Jules-Louis Breton referring to Cubist paintings as "jokes in bad taste" and objecting to their exhibition in the Grand Palais).

73 Reiss, *supra* note 46 at 32 (noting that critics "did not know what to make of" this new form of art). For a discussion of installation art as a paradigm shift, see *supra* note 46 and accompanying text.

74 See Sawyer, *supra* note 11 at 313–14. See also *supra* note 48 and accompanying text for a discussion of the paradigm shift introduced by *Star Wars*.

75 See Rogers, *supra* note 47 at 220.

76 See Kevin J Boudreau et al, "The Novelty Paradox and Bias for Normal Science: Evidence from Randomized Medical Grant Proposal Applications" (2012) Harvard Business School Working Paper No 13-053, online: <nrs.harvard.edu/urn-3:HUL.InstRepos:10001229>.

77 See *ibid* (demonstrating the existence of a "novelty discount" in the evaluation of highly novel applications).

78 See Brian Uzzi et al, "Atypical Combinations and Scientific Impact" (2013) 342:6157 Science 468 (impact was measured by the number of subsequent citations; novelty was measured by the frequency of combinations of references appearing in each paper). For further discussion of this novelty measure, see Part III.C., below.

elty often do not achieve the highest impact; rather, the papers most likely to obtain the highest impact are those that offer "an injection of novelty into an otherwise exceptionally familiar mass of prior work."[79]

Literature from diverse disciplines suggests various explanations for the preference of the incremental over the non-linear. Psychologist Wilfred Trotter observed long ago that "[t]he mind delights in a static environment," and "[c]hange from without ... seems in its very essence to be repulsive and an object of fear."[80] This observation has since been supported by psychological research identifying the confirmation bias, namely, the human tendency to seek confirmation of one's existing views and beliefs and to interpret new information accordingly.[81] Similar notions appear in socio-cultural literature maintaining that audiences of cultural works are often locked in familiar generic conventions; their exposure to formulaic, easy-to-digest works, particularly in the era of mass media, increases their appetite for "more of the same" and makes diverse and more complex forms of art more difficult to appreciate.[82] As a result, creators of new works often face commercial pressures toward conformity on behalf of studios, galleries, publishers, and other intermediaries.[83]

This lock-in within existing conventions is not confined to the general public, but is prevalent among experts and professionals too. Interestingly, specialists who are fully embedded in their domain may actually exhibit greater resistance to non-linear innovation.[84] On the other hand, more

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79 *Ibid* at 470.

80 Trotter, *supra* note 55 at 320. See also Barber, *supra* note 32 at 601 (maintaining that scientists think in "methodological preconceptions").

81 See e.g. Raymond S Nickerson, "Confirmation Bias: A Ubiquitous Phenomenon in Many Guises" (1998) 2:2 Rev General Psychology 175.

82 For prominent writers in this vein, see C Edwin Baker, *Media, Markets, and Democracy* (Cambridge: Cambridge University Press, 2001) at 87–92 (analyzing the inclination of media markets to focus on popular and formulaic work, and the circular effect it has on people's cultural tastes); Max Horkheimer & Theodor W Adorno, "The Culture Industry: Enlightenment as Mass Deception" in Max Horkheimer & Theodor W Adorno, *Dialectics of Enlightenment: Philosophical Fragments*, translated by Edmund Jephcott (Stanford: Stanford University Press, 2002) 94 (highlighting the forces pushing toward uniformity of works of mass culture and arguing that a uniform culture industry based on mass production suppresses individuality and criticism).

83 See Sawyer, *supra* note 11 at 10 (observing that "art markets and galleries pressure artists to continue working in the same recognizable style" while record companies pressure musicians to produce more hits like their first big hits). See also *ibid* at 314 (indicating that "[p]rofessional writers consciously stick with proven formulas, knowing that TV executives, advertisers, and viewers have grown to expect them").

84 See Boudreau et al, *supra* note 76 at 24 (finding that more accomplished evaluators tend to respond more negatively, in general, to research proposals that are distant from

peripheral actors with no central position in a field's professional network who are less immersed in its conventions may be able to step off the shoulders of giants more easily.[85] Wassily Kandinsky, regarded by many as the father of abstract painting, was a lawyer and only began painting at the age of thirty.[86] Gregor Mendel was an unknown monk when he introduced his theory of genetic inheritance,[87] and Louis Pasteur was an outsider to the medical profession when he advanced germ theory.[88] Yet, paradoxically, the relatively peripheral position of these innovators also hinders their chances to gain general acceptance when communicating their innovations to the rest of the network.[89]

Interestingly, the hard sciences are particularly uncomfortable with multiplicity and dissent and exhibit a stronger institutional tendency to cultivate the narrative of linear progress.[90] While the domains of culture and arts often address divergent, incommensurable, and opposing views, textbooks in the hard sciences regularly present their domain as a complete body of knowledge and frequently conceal shifts and discontinuities.[91] This inclination may explain why scientists who step off the shoulders of their predecessors sometimes downplay the non-linear nature of their paradigms. Newton, for example, allegedly undermined the revolutionary effect of the *Principia*,[92] while Darwin downplayed the revolutionary nature of his theory by devoting the first part of *On the Origin of Spe-*

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their field); Pedraza-Fariña, *supra* note 13 at 820 (arguing that specialization may, in some cases, constitute a barrier to innovation).

85 See Kuhn, *supra* note 9 at 90, 143 (indicating that paradigm shifts often emerge from people who are very young or new to the field); Howard Gardner, *Creating Minds: An Anatomy of Creativity Seen Through the Lives of Freud, Einstein, Picasso, Stravinsky, Eliot, Graham, and Ghandi* (New York: BasicBooks, 1993) at 360 (maintaining that the "[exemplary creator] comes from a locale somewhat removed from the actual centers of power and influence of her society").

86 See Sawyer, *supra* note 11 at 69–70.

87 See Barber, *supra* note 32 at 600.

88 See *ibid* at 601 (explaining that Pasteur was "a mere" chemist, not a medical specialist).

89 *See ibid* 600–01 (noting that Mendel was perceived as an "insignificant provincial" and Pasteur as a "mere chemist", which explains the "violent resistance" to their theories on part of the relevant authorities in the fields).

90 See Kuhn, *supra* note 9 at 139, 164–65.

91 See *ibid*.

92 See Uzzi et al, *supra* note 78 at 468 (observing that "Newton presented his laws of gravitation using accepted geometry rather than his newly developed calculus, despite the latter's importance in developing his insights"); Kuhn, *supra* note 9 at 139 (explaining that Newton credited "to Galileo the answer to a question that Galileo's paradigms did not permit to be asked").

cies to conventional knowledge.[93] These practices reinforce the popular image of scientists as participants in a long-standing and continuous tradition of accumulated progress, each standing on the shoulders of their predecessors.[94]

The analysis so far demonstrates that the non-linear innovation bias is a multicausal phenomenon that can be traced to various psychological, sociological, economic, and institutional factors.[95] Whatever its sources may be, this bias produces various externalities. In the field of culture and art, it may increase conformity and undermine diversity.[96] In the fields of science and technology, the non-linear innovation bias can lead to neglecting promising lines of research due to rejection, either by funding schemes[97] or by the relevant community.[98] As a result, the development and diffusion of valuable innovations may be delayed for decades due to their non-linear nature.[99] These delays, in turn, postpone the development of various applications, technologies, and follow-on works that are induced by non-linear innovations. The germ theory of disease is again illustrative. The acceptance of the theory triggered the development of pasteurization techniques and antibiotic drugs and revolutionized medicine in several respects.[100] Yet, the theory was fiercely resisted for a long time and, during the long decades that preceded its acceptance, surgery in hos-

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93 See Uzzi et al, *supra* note 78 at 468.

94 See Kuhn, *supra* note 9 at 137.

95 To this long list of causes, one can also add culturally embedded factors that are discussed in Part IV, below.

96 See *supra* notes 82–83 and accompanying text.

97 See Daryl E Chubin & Edward J Hackett, *Peerless Science: Peer Review and US Science Policy* (Albany: State University of New York Press, 1990) at 63–65 (presenting empirical evidence that a significant percentage of the scientists in the natural sciences whose grant applications are rejected stop pursuing the proposed line of research); Boudreau et al, *supra* note 76 and accompanying text. See also Pedraza-Fariña, *supra* note 13 at 847 (describing the difficulties in obtaining funding for bioengineering projects that were considered unconventional in engineering and biology, which delayed the development of the field).

98 See e.g. Barber, *supra* note 32 at 600 (describing how the cold response from the scientific community led Gregor Mendel to pursue a different line of research, which resulted in Mendel "labor[ing] in a blind alley for the rest of his scientific life").

99 See e.g. *ibid* at 598 (describing how the theory of genetic inheritance was practically ignored for thirty years before it was "rediscovered" by others, this time to gain general acceptance); Trotter, *supra* note 55 at 319 (describing the delayed diffusion of the molecular theory of gases due to disregard of its innovator, JJ Waterston, whose work lay "in utter oblivion" for forty-five years).

100 See Herbst, *supra* note 32 at 30–32, 70–71.

pitals was so dangerous that it almost became extinct.[101] The non-linear innovation bias, then, can certainly harm progress.

III. Non-Linear Innovation and Intellectual Property

What are the potential implications of the foregoing analysis for intellectual property policy and doctrine? Can intellectual property law encourage non-linear innovation or facilitate stepping off giants' shoulders? Before exploring these questions in specific doctrinal contexts, one needs to address several preliminary doubts and potential objections concerning the ability of intellectual property law to play a significant role in promoting non-linear innovation.

A. Does Intellectual Property Have a Role?

A first possible objection concerns the adequacy of intellectual property law as a tool for mitigating the non-linear innovation bias in light of the sources and origins of this bias. The preceding discussion indicates that the non-linear innovation bias is a multicausal phenomenon entrenched in various social dynamics. It does not originate in intellectual property law. Indeed, it would be unrealistic to expect that certain calibrations in intellectual property doctrine would be sufficient to completely overcome it.[102] And yet, intellectual property is the one area of law explicitly delegated with the mission of promoting innovation.[103] As such, it cannot confine its efforts to incremental innovation. The following sub-parts demonstrate that, even if intellectual property law is not the primary source of the problem and cannot provide a perfect de-biasing mechanism, it can still be part of the solution and adopt several significant measures to facilitate and foster non-linear innovation.

Secondly, the foregoing discussion indicates that many non-linear innovations in the field of science and technology are conceived in the context of academic research and basic science. Plausibly, the primary motivations of their innovators are not intellectual property-related. Some of these innovations may even be considered "laws of nature, physical phe-

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[101] See Trotter, *supra* note 55 at 318. For additional discussion of the delayed diffusion of non-linear innovations and the entailed social costs, see Part III.C., below.

[102] See Michal Shur-Ofry, "IP and the Lens of Complexity" (2013) 54:1 IDEA 55 at 96–101 [Shur-Ofry, "Complexity"] (highlighting the absence of a linear causal connection between various intellectual property reforms and desired social ends).

[103] For a famous reflection of the incentive rationale of intellectual property, see US Const art I, § 8, cl 8 ("[t]he Congress shall have the Power ... [t]o promote the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries").

nomena, and abstract ideas" that constitute non-patentable subject-matter.[104] Are non-linear innovations susceptible to the set of incentives offered by the intellectual property system, particularly by patent law?

While the answer to this question is very much context dependent, as a general matter, non-linear innovations are not oblivious to intellectual property regimes. For one thing, the distinction between patentable and non-patentable subject matter is ever blurry, and has been extensively engaging the courts in recent years.[105] While some non-linear innovations may not qualify for patent protection, others may well do. More importantly, scholarship has long recognized that the distinction between basic science (that is ostensibly non-commercial, theoretical, and oblivious to intellectual property incentives) and downstream industry (that is presumably commercial, practical, and strictly motivated by such incentives) is far from dichotomous.[106] Innovators who are chiefly motivated by intellectual curiosity or reputational concerns can still be sensitive to intellectual property incentives. In fact, numerous academic institutions, as well as individual innovators, patent various applications that stem from their non-linear innovations. Louis Pasteur, who patented a pasteurization technology that followed from the germ theory paradigm shift, is one example.[107] In addition, non-linear innovations often encounter difficulties in

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[104] *Diamond v Chakrabarty*, 447 US 303 at 309, 100 S Ct 2204 (1980). See also *Patent Act*, RSC 1985, c P-4, s 27(8) [Canada *Patent Act*] ("[n]o patent shall be granted for any mere scientific principle or abstract theorem").

[105] For prominent recent decisions of the US Supreme Court attempting to define the scope of patentable versus non-patentable subject matter, see *Bilski v Kappos*, 561 US 593, 130 S Ct 3218 (2010); *Mayo Collaborative v Prometheus Labs*, 132 S Ct 1289, 182 L Ed (2d) 321 (2012); *Ass'n for Molecular Pathology v Myriad*, 133 S Ct 2107, 186 L Ed (2d) 124 (2013); *Alice Corp v CLS Bank Int'l*, 134 S Ct 2347, 189 L Ed (2d) 296 (2014).

[106] See e.g. Rebecca S Eisenberg, "Proprietary Rights and the Norms of Science in Biotechnology Research" (1987) 97:2 Yale LJ 177 at 178, n 1 (doubting the validity of the dichotomy between "pure" and "applied" research in the biotechnology field); Arti K Rai & Rebecca S Eisenberg, "Bayh-Dole Reform and the Progress of Biomedicine" (2003) 66:1&2 Law & Contemp Probs 289 at 289 (indicating that the gap between fundamental research and commercial applications in biomedical research has narrowed); Suzanne Scotchmer & Stephen M Maurer, "Innovation Today: A Private-Public Partnership" in Suzanne Scotchmer, *Innovation and Incentives* (Cambridge, Mass: MIT Press, 2004) 227 at 235–40 (describing various cooperation schemes between university researchers and industry); Peter Lee, "Interface: The Push and Pull of Patents" (2009) 77:5 Fordham L Rev 2225 at 2226–33 (observing that the lines between "basic" and "applied" research, and between non-commercial and commercial research, are increasingly blurring).

[107] See "Improvement in Brewing Beer and Ale", US Patent No 135245 (28 January 1873). Similarly, some of the cervical cancer vaccines that were developed following the virus-cancers paradigm shift were patented by the scientists and institutions that contributed to the emergence of the new paradigm (see e.g. "Papillomavirus Vaccine", US Patent No 7169585 (11 December 2003)).

obtaining government funding.[108] Therefore, their inventors may be more dependent on industry sources or venture capital funds which in turn may attribute particular importance to patent protection.[109] Last, non-linear innovation can certainly occur in non-academic, industry settings.[110]

Moreover, and importantly, even when non-linear innovations are not motivated by intellectual property incentives and do not seek intellectual property protection, the prevalent intellectual property regime can still affect them. The analysis in the following paragraphs demonstrates that certain acts that typically pave the way to paradigm shifts require certain use of copyrighted works or patent protected inventions.[111] By delineating the contours of intellectual property rights and determining whether such uses are permitted, or conversely, infringing, the intellectual property system can either simplify or impede non-linear innovations.

A final concern relates to the possible social costs of facilitating non-linear innovation through the intellectual property system. Admittedly, not all innovations that initially seem radical and non-linear lead to valuable progress. In time, some ostensibly revolutionary inventions turn out to be completely erroneous. Allegedly, then, adjusting the intellectual property system to better promote non-linear innovation may sometimes result in affording intellectual property protection to failures and even fiascos. Yet, a closer examination clarifies that this concern should not be overemphasized. Intellectual property protection does not replace scientific screening or market mechanisms against which non-linear innovations are ultimately measured. When a certain innovation turns out to be a failure, it will neither become a platform for subsequent inventions nor result in extensive licensing.[112] Therefore, calibrating the intellectual property system toward non-linear innovations will not likely impose significant social costs.

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[108] See generally Boudreau et al, *supra* note 76 and accompanying text.

[109] See e.g. Michael Abramowicz & John F Duffy, "The Inducement Standard of Patentability" (2011) 120:7 Yale LJ 1590 at 1676 (indicating that venture capitalists may refrain from funding risky projects absent patent protection).

[110] See Pedraza-Fariña, *supra* note 13 at 855 (observing that social dynamics impacting innovation are likely to occur in industries too since their scientists are often trained in academia).

[111] See the discussion of "access" in Part III.B., below.

[112] See Brenda M Simon, "Rules, Standards and the Reality of Obviousness" (2014) 65:1 Case W Res L Rev 25 at 46 (indicating that many patents are never asserted or licensed, possibly because the technologies they cover "are not that valuable").

The following sub-parts proceed to explore how intellectual property doctrines can better accommodate non-linear innovation.[113] This examination relies on a close look at the attributes of such innovation, and focuses on three central aspects that are tightly linked to those traits. The first concerns access and inquires which policy of access to intellectual property-protected subject matter will best foster non-linear innovation. The second aspect concerns time. It focuses on the slower diffusion of non-linear innovations and explores the implications for patent and copyright doctrines. The third sub-part highlights specific traits of non-linear innovations that emerge from recent network analyses. It demonstrates how intellectual property doctrine can use these insights to more accurately identify non-linear innovations and provide them with targeted de-biasing mechanisms.

B. Access

> [N]ovelty ordinarily emerges only for the man who, knowing *with precision* what he should expect, is able to recognize that something has gone wrong.[114]

Conventional wisdom in intellectual property scholarship maintains that cumulative innovation necessitates access to intellectual property-protected subject matter such as patented inventions or copyrighted works; in order to stand on the shoulders of giants, one needs to make certain use of their works and inventions.[115] Hence, the incremental nature of innovation and creation constitutes grounds for facilitating access to works of authorship and technological inventions by limiting the control of the right owners over such subject matter.[116]

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[113] Notably, while this Part focuses primarily on American and Canadian intellectual property doctrines, much of the analysis is jurisdictionally agnostic and could broadly apply to equivalent intellectual property doctrines in various jurisdictions.

[114] Kuhn, *supra* note 9 at 65 [emphasis in original].

[115] See e.g. Dutfield & Suthersanen, *supra* note 6 at 379 (indicating that one of the key implications of the incremental and cumulative nature of most innovations is that the creation of new works requires accessing and using pre-existing copyright protected works); Tom Saunders, "Renting Space on the Shoulders of Giants: *Madey* and the Future of the Experimental Use Doctrine", Case Comment, (2003) 113:1 Yale LJ 261 at 265 (maintaining that the incremental nature of innovation mandates a broader experimental use exception in patent law); McKenna & Strandburg, *supra* note 6 at 45–46 (making similar observations concerning access to design-protected subject matter); James Bessen & Eric Maskin, "Sequential Innovation, Patents, and Imitation" (2009) 40:4 RAND J Econ 611 at 612–13 (discussing the importance of access and imitation for sequential innovation).

[116] See *supra* note 115.

Should the desire to encourage non-linear innovation guide intellectual property policy in an opposite direction, namely toward a policy of enclosure which burdens such access? Prominent scholars indeed maintained that adopting certain enclosure policies in patent law—for example, the strict enforcement of patents over research tools or the absence of an experimental use exception—may encourage the generation of alternative solutions and spark paradigm shifts.[117] Yet, a closer look indicates that solitude and restriction of access are not the main route to non-linear innovation. Paradigm shifts are not born in a vacuum, but require deep familiarity with the current state of the art. This kind of thorough knowledge allows identification of errors and anomalies in existing scientific theories and technologies, which in turn directs innovators toward alternatives.[118] Even those discoveries and inventions that are sometimes attributed to serendipity do not result from mere chance; when novelty reveals itself, it still requires a thorough knowledge of a field in order to notice it and realize its significance.[119] The story of Shechtman is again illustrative: several scientists encountered quasi-periodic crystals before Shechtman did, but discarded the discovery without recognizing its potential implications.[120]

Creativity in the artistic and cultural domains likewise develops against a background of prior works.[121] Acquaintance with existing works enables authors to internalize the symbols and conventions of the domain, which in turn allows deviation from those conventions and generation of novel insights or new artistic and cultural languages.[122]

This analysis yields several important and counterintuitive guidelines for intellectual property policy. First, as a general matter, access to intellectual property-protected subject matter is important for both linear *and* non-linear innovation; while incremental innovators require access in or-

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[117] See e.g. Lee, *supra* note 13 at 690–91. For a somewhat similar argument in the field of copyright, see Joseph P Fishman, "Creating Around Copyright" (2015) 128:5 Harv L Rev 1334 (maintaining that the restriction of access to copyright-protected works may encourage creativity).

[118] See Kuhn, *supra* note 9 at 65. In a recent conversation, Dan Shechtman expressed a similar sentiment, stressing that deep knowledge and professionalism are crucial preconditions for paradigm shifts (Shechtman, *supra* note 2).

[119] See Kuhn, *supra* note 9 at 65. *Cf* Barber, *supra* note 32 at 598 (discussing examples of scientists who failed to make discoveries although the facts were "before their eyes").

[120] See e.g. Asaf Shtull-Trauring, "Clear as Crystal", *Haaretz* (1 April 2011), online: <www.haaretz.com/weekend/magazine/clear-as-crystal-1.343504>.

[121] See Sawyer, *supra* note 11 at 93.

[122] See *ibid* at 140 ("[n]o one can be creative until he or she internalizes the symbols, conventions, and languages of a creative domain").

der to build on existing works and inventions, non-linear innovators need such access both for internalizing the conventions of a domain, as well as for exposing errors, failures, and misconceptions in these conventions. This analysis further implies that *the relations between incremental and non-linear innovation are not completely dichotomous*; to a certain extent, stepping off the shoulders of giants first requires standing on their shoulders.[123] In other words, a policy that facilitates access to intellectual property-protected works and technologies does not merely promote incremental works and inventions, it can also foster non-linear types of innovation.

Second, a policy that seeks to promote non-linear innovation must take into account the particular kind of access that will benefit this type of innovation. Most prominently, it cannot confine itself to access to substantial information and knowledge. Rather, it must also be concerned with providing access to negative information, including errors, mistakes, disconfirmations, and additional types of negative knowledge. The foregoing discussion indicates that paradigm shifts in the field of science and technology are often preceded by identifying anomalies, errors, counter-instances, and misconceptions in prevalent paradigms.[124] Yet, so far, access to negative information has been largely overlooked by intellectual property policy.[125] Nevertheless, my analysis indicates that access of this kind can be especially significant for inducing non-linear innovation.

Against these insights, the next paragraphs briefly review three access-facilitating mechanisms in intellectual property law through the prism of non-linear innovation: (1) copyright's fair use doctrine; (2) patent law's experimental use exception; and (3) patent law's disclosure requirements.

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[123] See Uzzi et al, *supra* note 78 at 471 (maintaining that "novelty and conventionality are not factors in opposition"). See also the network analyses of breakthrough inventions discussed in Part III.D., below (especially *infra* notes 195–200 and accompanying text).

[124] See Introduction and Part I, above. See also Kuhn, *supra* note 9 at 53; Bacon, *supra* note 25 at 210 (emphasizing the importance of errors for "truth"); Popper, *Conjectures*, *supra* note 26 at xi–xii (highlighting the significance of refutations for scientific progress); Nassim Nicholas Taleb, *Antifragile: Things That Gain from Disorder* (New York: Random House, 2012) at 79 (maintaining that negative information is central to entrepreneurship).

[125] For a detailed exploration of the insufficient legal incentives to disclose and disseminate negative information within and beyond intellectual property law, see Michal Shur-Ofry, "Access to Error", Cardozo Arts & Ent LJ [forthcoming in 2016], online: <papers.ssrn.com/sol3/papers.cfm?abstract_id=2693464> [Shur-Ofry, "Error"]. See also Amy Kapczynski & Talha Syed, "The Continuum of Excludability and the Limits of Patents" (2013) 122:7 Yale LJ 1900 at 1923–28; Sean B Seymore, "The Null Patent" (2012) 55:6 Wm & Mary L Rev 2041.

1. Fair Use in Copyright Law

The fair use—or fair dealing—doctrine in copyright law permits certain uses of copyrighted material without the owners' consent and constitutes the principal limitation to the exclusive rights of copyright owners.[126] While the fair use doctrine is far from perfect,[127] it does play an important role in facilitating non-linear innovation. Most importantly, the doctrine recognizes the significance of access for purposes of contradiction, dissent, and discontinuity. The statutory provisions explicitly address acts of "criticism", "review", "comment", and "research" among the paradigmatic purposes that may constitute fair use or fair dealing.[128] In addition, under the fair use analysis, the "transformative" nature of a use constitutes an indication of its fairness.[129] The doctrine's implementation in case law suggests, too, that the use of copyright-protected works by a third party in a discontinuous manner, in order to contradict or disrupt prevailing cultural paradigms, is often deemed fair and non-infringing. For example, Alice Randall's book *The Wind Done Gone*,[130] which offered a reinterpretation of *Gone with the Wind* and a shift from the depiction of race relations in the original novel, was pronounced a permitted fair use.[131] Likewise,

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[126] See 17 USC § 107 (2011) [US *Copyright Law*]; *Copyright Act*, RSC 1985, c C-42, s 29 [*Copyright Act*]. For an interesting account of the differences between the American "fair use" and Canadian "fair dealing" doctrines, see Ariel Katz, "Fair Use 2.0: The Rebirth of Fair Dealing in Canada" in Michael Geist, ed, *The Copyright Pentalogy: How the Supreme Court of Canada Shook the Foundations of Canadian Copyright Law* (Ottawa: University of Ottawa Press, 2013) 93.

[127] Fair use has been criticized by various scholars, mostly due to its inherently uncertain nature (see e.g. James Gibson, "Risk Aversion and Rights Accretion in Intellectual Property Law" (2007) 116:5 Yale LJ 882 at 887–90; Jason Mazzone, "Administering Fair Use" (2009) 51:2 Wm & Mary L Rev 395 at 400–01). *Cf* Matthew Sag, "Predicting Fair Use" (2012) 73:1 Ohio St LJ 47 (presenting empirical research that identifies influential factors in the application of fair use by courts).

[128] US *Copyright Law*, *supra* note 126, § 107 ("the fair use of a copyrighted work ... *for purposes such as criticism, comment*, news reporting, teaching ... scholarship, *or research*, is not an infringement of copyright" [emphasis added]); *Copyright Act*, *supra* note 126, ss 29–29.1 ("[f]air dealing for the purpose of *research*, private study, education, parody or satire does not infringe copyright. ... Fair dealing for the purpose of *criticism* or *review* does not infringe copyright" [emphasis added]).

[129] See *Campbell v Acuff-Rose Music, Inc*, 510 US 569, 114 S Ct 1164 at 1171 (1994); Pierre N Leval, "Toward a Fair Use Standard" (1990) 103:5 Harv L Rev 1105 at 1111 (highlighting the significance of the "transformative" nature of the challenged use).

[130] Alice Randall, *The Wind Done Gone* (Boston: Houghton Mifflin, 2001).

[131] See *Suntrust Bank v Houghton Mifflin Co*, 268 F (3d) 1257, 2001 WL 1193890 (11th Cir 2001). Randall's book told the story of Margaret Mitchell's *Gone with the Wind* from the slaves' viewpoint (see Randall, *supra* note 130).

Tom Forsyth's display of *Nude Barbie* in an art installation that challenged gender stereotypes was proclaimed fair.[132]

Yet, the non-linear innovation perspective does not merely yield praise for fair use. It also provides normative guidelines for its application in more disputed circumstances. One example concerns cases of appropriation art, a cultural genre that regularly uses existing imagery and was the centre of several copyright disputes.[133] Often, a principal question in such cases is whether the defendant's use of a copyrighted image constitutes fair comment or is "transformative" enough when it does not directly criticize the original image.[134] Facilitating non-linear innovations implies that fair use (and fair dealing) should not be limited to uses that directly comment on the original copyrighted work, but should extend to uses that dispute existing conventions by way of general social critique.[135] All in all, however, the explicit focus of the fair use doctrine on discontinuity and change makes it an important tool for facilitating non-linear innovations in the cultural and artistic sphere.

2. Experimental Use in Patent Law

Patent law's parallel mechanism reveals a different picture. The main limitation on the rights of patent holders is the experimental use exception. The exception allows certain uses of patent-protected inventions for purposes that would otherwise constitute patent infringement and is comprised of two branches: the primary exception, which is common law based,[136] and a more recent statutory exception that applies to the phar-

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[132] See *Mattel Inc v Walking Mountain Productions*, 353 F (3d) 792, 2003 WL 23018285 (9th Cir 2003).

[133] For prominent case law in the United States, see *Cariou v Prince*, 714 F (3d) 694, 2013 WL 1760521 (2nd Cir 2013) [*Cariou*]; *Rogers v Koons*, 960 F (2d) 301, 60 USLW 2682 (2nd Cir 1992), cert denied, *Koons v Rogers*, 506 US 934, 113 S Ct 365 (1992) [*Rogers*].

[134] See generally "Copyright Law – Fair Use – Second Circuit Holds That Appropriation Artwork Need Not Comment on the Original to Be Transformative – *Cariou v Prince*, 714 F 3d 694 (2d Cir 2013)", Case Comment, (2014) 127:4 Harv L Rev 1228 (discussing the application of the "transformativeness" standard in cases of appropriation art); E Kenly Ames, "Beyond *Rogers v Koons*: A Fair Use Standard for Appropriation" (1993) 93:6 Colum L Rev 1473 (describing the difficulties in viewing appropriation art which makes general social criticism as fair comment).

[135] For diverging views on this point in case law, see e.g. *Rogers*, *supra* note 133 at 310 (holding that "the copied work must be, at least in part, an object of the parody"). *Cf Cariou*, *supra* note 133 at 706 ("[t]he law imposes no requirement that a work comment on the original or its author in order to be considered transformative").

[136] See *Whittemore v Cutter*, 29 F Cas 1120 at 1121 (Mass Cir Ct 1813) [*Whittemore*]. For the adoption of the common law experimental use exception in Canada, see *Micro Chemicals Ltd v Smith Kline & French Inter-American Corp* (1971), [1972] SCR 506 at

maceutical field.[137] Yet, a close look reveals that neither of these branches facilitate non-linear innovation.

Interestingly, the common law exception as initially crafted by American courts two centuries ago did recognize the legitimacy of using patented products for purposes of "evaluation, ascertaining and verification" of patented inventions.[138] Such an interpretation potentially allows for the testing of existing inventions in order to detect errors and failures in their underlying technologies. As indicated earlier, this type of access is often a vital step on the way to paradigm shifts.[139] Yet modern American case law has dramatically narrowed the scope of the exception, carving out all research performed out of a commercial motive or for promoting "legitimate business objectives,"[140] including basic university research with "no commercial application whatsoever."[141] These limitations practically drain the exception of its potential to facilitate both non-linear and incremental innovation, as they filter out the vast majority of players who could possibly engage in innovative activity—both in industry and academia. The situation in Canada is only slightly better from the perspective of non-linear innovation. While Canadian case law generally adopts a more expansive approach toward the experimental use exception,[142] the applicability of the exception to acts that are not related to *improving* the invention is

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518–20, 25 DLR (3d) 79. See also Stephen J Ferance, "The Experimental Use Defence to Patent Infringement" (2004) 20 CIPR 1.

137 See 35 USC § 271(e) [US *Patent Act*]; Canada *Patent Act*, *supra* note 104, s 55.2. See also Robert H Barrigar, *Canadian Patent Act Annotated* (Aurora, Ont: Canada Law Book, 1994) (loose-leaf revision July 2004) at PA-232.1–232.2 (although the Canadian statutory exception, unlike its US counterpart, is not confined to pharmaceuticals, case law "clearly reveals that the principal industry affected is the pharmaceutical industry [and] the patents in question are largely pharmaceutical patents").

138 See *Whittemore*, *supra* note 136 at 1121 ("it could never have been the intention of the legislature to punish a man, who constructed such a machine merely *for philosophical experiments*, or for the purpose of *ascertaining the sufficiency of the machine to produce its described effects*" [emphasis added]). These statements were reinforced in *Sawin v Guild*, 21 F Cas 554 at 555 (Mass Cir Ct 1813) ("the making of a patented machine ... for the mere purpose of philosophical experiment" does not constitute patent infringement).

139 See *supra* notes 117–20 and accompanying text.

140 See *Madey v Duke University*, 307 F (3d) 1351 at 1362, 64 USPQ (2d) 1737 (Fed Cir App Ct 2002), cert denied, *Duke Unviersity v Madey*, 539 US 958, 123 S Ct 2639 (2003).

141 *Ibid*.

142 See Ferance, *supra* note 136 at 33–34 (explaining that experiments that further commercial purposes may still be covered by the experimental use defence under Canadian law).

still uncertain.[143] Thus, the Canadian position as regards experiments whose purpose is not building upon the invention but rather exposing its fallibilities is at best unclear.

The statutory exceptions, too, do not change the picture for non-linear innovation. The provisions allow the use of patented inventions for the purpose of product development if such use is "reasonably related" to the preparation of information submitted to regulatory authorities.[144] The American exception was construed by the US Supreme Court as extending to the use of patented inventions in preclinical research that is not ultimately included in the submission to the Food and Drug Administration (FDA).[145] However, this (relatively broad) construction does not aid non-linear innovation. In order to benefit from the exception, the permitted experimental use still needs to be somewhere "on the road to regulatory approval," with a "reasonable basis for believing" that the new product might work.[146] These requirements exclude uses the ultimate purpose of which is not the creation of a new product, but rather the scrutiny of existing technologies, in order to detect failures, identify mistakes, and find out what does not work. Yet, these are exactly the acts that can pave the way for non-linear innovations.

Numerous scholars describe the US experimental use exception as overly narrow.[147] This literature generally maintains that the exception

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[143] See *ibid* at 36 (explaining that, although the defence was expanded beyond "improving the invention, ... the present and future status of the expanded defence is uncertain" due to subsequent revisions in the *Patent Act*).

[144] US *Patent Act*, *supra* note 137, § 271(e) ("[i]t shall not be an act of infringement to make, use, offer to sell, or sell within the United States or import into the United States a patented invention ... solely for uses reasonably related to the development and submission of information under a Federal law which regulates the manufacture, use, or sale of drugs or veterinary biological products"); Canada *Patent Act*, *supra* note 104, s 55.2(1) ("[i]t is not an infringement of a patent ... to make, construct, use or sell the patented invention solely for uses reasonably related to the development and submission of information required under any law ... that regulates the manufacture, construction, use or sale of any product").

[145] See *Merck KGaA v Integra Lifesciences I Ltd*, 545 US 193 at 207, 125 S Ct 2372 (2005).

[146] *Ibid*.

[147] See e.g. Rebecca S Eisenberg, "Patents and the Progress of Science: Exclusive Rights and Experimental Use" (1989) 56:3 U Chicago L Rev 1017 [Eisenberg, "Progress of Science"]; Janice M Mueller, "No 'Dilettante Affair': Rethinking the Experimental Use Exception to Patent Infringement for Biomedical Research Tools" (2001) 76:1 Wash L Rev 1; Saunders, *supra* note 115; Katherine J Strandburg, "What Does the Public Get?: Experimental Use and the Patent Bargain" (2004) Wis L Rev 81; Wendy Thai, "Toward Facilitating Access to Patented Research Tools" (2004) 6 Minn JL Sci & Tech 373; Ofer Tur-Sinai, "Cumulative Innovation in Patent Law: Making Sense of Incentives" (2010) 50:4 IDEA 723 at 750–52.

must be expanded in order to facilitate follow-on inventions.[148] The analysis here illuminates an additional important justification for such an expansion. It suggests that a broader experimental use exception is desirable not only for facilitating improvements or developing follow-on inventions, but also for allowing deeper scrutiny of existing inventions, exposing errors in underlying technologies, and falsifying prevalent assumptions—all of which constitute vital steps on the way to paradigm shifts. It further implies that any adjustment or clarification to the experimental use exception, either in the United States or in Canada, should not be limited to facilitating cumulative inventions, but should also explicitly consider non-linear innovation.

3. Patent Law's Disclosure Requirements

Lastly, the significance of mistakes and failures for inducing non-linear innovations sheds new light on the disclosure requirements in patent law. Briefly, in order to obtain a valid patent, a patentee is required to disclose sufficient information about her invention. The required disclosure should enable a person skilled in the art to make the claimed invention and use it (the enablement requirement).[149] In addition, the patent documents need to specify the "best mode contemplated by the inventor ... of carrying out the invention" (the best mode requirement).[150] Conventional wisdom regards disclosure as the tenet of the quid pro quo bargain between the patentee and the public; in exchange for the powerful right to exclude, society receives valuable information about the invention that will allow others to make it upon patent expiry.[151]

The scope of the disclosure requirements has long been the subject of scholarly discussion,[152] and attracts renewed interest following the patent

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[148] See *supra* note 147.

[149] See US *Patent Act*, *supra* note 137, § 112(a); Canada *Patent Act*, *supra* note 104, s 27(3)(b).

[150] See US *Patent Act*, *supra* note 137, § 112(a). See also Canada *Patent Act*, *supra* note 104, s 27(3)(c) (requiring disclosure of best mode "in the case of a machine"). For a general discussion of these requirements, see Sheldon W Halpern, Craig Allen Nard & Kenneth L Port, *Fundamentals of United States Intellectual Property Law: Copyright, Patent, Trademark*, 3rd ed (Alphen aan den Rijn, The Netherlands: Kluwer Law International, 2011) at 197–203; David Vaver, "Best Mode Disclosure in Canadian Patents" (2013) 25:3 IPJ 303 (arguing that the disclosure of the best mode is the basis for the grant of exclusive rights to the inventor and maintaining that the requirement to disclose the best mode is part of Canada's patent law).

[151] See Halpern, Nard & Port, *supra* note 150 at 199.

[152] See e.g. Christopher S Marchese, "Promoting the Progress of the Useful Arts by Narrowing Best Mode Disclosure Requirements in Patent Law" (1993) 54:2 U Pitt L Rev 589; Dale L Carlson, Katarzyna Przychodzen & Petra Scamborova, "Patent Linchpin

law reform recently introduced in the United States by the *Leahy-Smith America Invents Act*.[153] Yet, the ongoing debates overlook an important aspect of patent disclosure: patent law's disclosure requirements, much like its experimental use exception, are largely based on the narrative of cumulative innovation. A prominent justification for the disclosure requirements is allowing improvements and follow-on inventions.[154] While the inventor is obliged to disclose positive information about her invention that will assist those wishing to use it or build upon it, no disclosure is required with respect to failed modes, neglected approaches, errors, absences, or other negative knowledge surrounding the invention. Such information, despite its potential to induce non-linear innovations, may well remain confidential and enjoy the protection of trade secret law.[155]

I am not suggesting here a detailed reform of patent law's disclosure requirements. Admittedly, unilateral disclosure of the trade secrets surrounding many patented technologies may disrupt the delicate incentive-access balance underlying the patent system. I am proposing, in a broader sense, that patent law's disclosure requirements should not focus merely on facilitating incremental innovation, but should be re-tailored to foster non-linear innovation as well. One tentative direction could be offering additional incentives for patentees who choose to disclose negative information and provide access to failures, incommensurable results, blind al-

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for the 21st Century?: Best Mode Revisited" (2005) 45:3 IDEA 267; Fromer, "Patent Disclosure", *supra* note 6 (arguing that the disclosure function is "underperforming" and proposing various measures to improve disclosure); Lisa Larrimore Ouellette, "Do Patents Disclose Useful Information?" (2012) 25:2 Harv JL & Tech 545.

153 *Leahy-Smith America Invents Act*, 125 Stat 284 (2011) [*AIA*]. For a discussion and criticism of amendments introduced by the *AIA* concerning the best mode disclosure requirement, see Brian J Love & Christopher B Seaman, "Best Mode Trade Secrets" (2012) 15:1 Yale JL & Tech 1; Lee Petherbridge & Jason Rantanen, "In Memoriam Best Mode" (2012) 64 Stan L Rev Online 125, online: <www.stanfordlawreview.org/online/in-memoriam-best-mode> (analyzing the impact of the *AIA* on best mode disclosure).

154 See Fromer, "Patent Disclosure", *supra* note 6 at 541 ("[p]atent law is premised on the onward march of science and technology. ... Patent law encourages this cumulative innovation ... by requiring [the inventor] to disclose his invention to the public so that science can progress by building on the divulged knowledge"); Halpern, Nard & Port, *supra* note 150 at 199 (noting that one of the purposes of the enablement requirement is to allow "competitors ... [to] *improve* upon the claimed invention" [emphasis added]); Carlson, Przychodzen & Scamborova, *supra* note 152 at 269–70 (stressing the importance of disclosing the best mode for improving existing inventions).

155 See e.g. *R2 Medical Systems Inc v Katecho Inc*, 931 F Supp 1397 (ND Ill 1996) (trade secrets may cover information that lies outside of the disclosure requirements of the claimed invention); Eisenberg, "Progress of Science", *supra* note 147 at 1029, n 52 (referring to a practice of patent applicants to withhold information from patent specifications and continue to protect their know-how as trade secrets).

leys, or similar negative knowledge at the penumbra of their patented technologies.[156]

C. Time

> [T]he greatest benefactors of mankind usually do not obtain a full reward during their life-time ... new ideas need the more time for gaining general assent the more really original they are.[157]

An additional prominent trait of non-linear innovations concerns the rate of their diffusion in the relevant network. Part II illustrates that the spread of valuable innovations can be delayed for decades due to their non-linear nature.[158] This is no coincidence. Laura Pedraza-Fariña recently indicated that sociological factors can contribute to innovative delay.[159] Diffusion research further instructs that the more an innovation is perceived as consistent with existing values and past experiences, the faster it will spread, and vice versa.[160] Therefore, the diffusion of non-linear innovations is likely to be slower than the diffusion of cumulative and incremental ones, either due to difficulty of the relevant professional community to accept the new paradigm,[161] or due to its slow spread among the general public.[162] To illustrate, several decades lapsed between the introduction of the theory of genetic inheritance and its successful diffusion within the scientific community;[163] between the introduction of germ theory of disease and the spread of sterilization technologies in hospitals;[164] between the first works in the genre of installation art and their assimila-

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156 For additional discussion of adjustments to patent disclosure in order to facilitate access to negative knowledge, see Shur-Ofry, "Error", *supra* note 125.

157 Barber, *supra* note 32 at 596, citing Robert H Murray, *Science and Scientists in the Nineteenth Century* (London: Sheldon Press, 1925) at 103.

158 See Part II, especially *supra* notes 65–69, 99–100 and accompanying text.

159 See Pedraza-Fariña, *supra* note 13 at 850 (further maintaining that patent law should take such factors into account).

160 See Rogers, *supra* note 47 at 240–49 (discussing the "compatibility" of an innovation to prevailing social norms and its positive impact on the rate of adoption).

161 See the discussion in Part II, *supra* notes 58–69, 84–89 and accompanying text.

162 See Rogers, *supra* note 47 at 240–49; A Samuel Oddi, "Beyond Obviousness: Invention Protection in the Twenty-First Century" (1989) 38:4 Am UL Rev 1097 at 1126 (maintaining that "conventional inventions ... find ready channels for production and marketing" and therefore spread more quickly than non-conventional inventions).

163 See *supra* notes 63–64 and accompanying text.

164 See *supra* notes 99–101 and accompanying text.

tion into mainstream galleries;[165] and between the introduction of rap music in the United States and its adoption by mainstream audiences.[166] The slow diffusion of Kuhn's book is perhaps the ultimate—and self-referential—example of this phenomenon: *The Structure* sold less than a thousand copies when it was first published in 1962. Twenty-five years later, its success was undeniable with sales in 1987 reaching hundreds of thousands.[167]

How can intellectual property law take into consideration the slow diffusion of non-linear innovations? The following paragraphs explore this question by focusing on two doctrines. The first is the doctrine of *droit de suite* in copyright law. The second is the test of commercial success in patent law.

1. *Droit de Suite* in Copyright Law

A close look at copyright law reveals again that this branch of intellectual property is somewhat inclined, even if inadvertently, to accommodate non-linear innovations. Copyright's sensitivity to slowly diffusing innovations is most evident in the doctrine of *droit de suite*. Set out in the *Berne Convention*, *droit de suite* entitles creators of works of art and manuscripts to a share in the proceeds from the subsequent resale of their original works.[168] By so doing, the doctrine of *droit de suite* implicitly recognizes that success is not always instant and that attaining public recognition can be a gradual and long process.[169]

While the *Berne Convention* provides that the implementation of *droit de suite* is optional, more than seventy countries have so far introduced

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[165] See Reiss, *supra* note 46 at xv.

[166] See Rogers, *supra* note 47 at 220–21.

[167] See Hacking, *supra* note 9 at xxxvii.

[168] *Berne Convention for the Protection of Literary and Artistic Works*, 9 September 1886, 828 UNTS 221, art 14*ter* (entered into force 5 December 1887) ("(1) [t]he author, or after his death the persons or institutions authorized by national legislation, shall, with respect to original works of art and original manuscripts of writers and composers, enjoy the inalienable right to an interest in any sale of the work subsequent to the first transfer by the author of the work").

[169] See Sam Ricketson, *The Berne Convention for the Protection of Literary and Artistic Works: 1886–1986* (London: Centre for Commercial Law Studies, Queen Mary College & Kluwer, 1987) at 410–11; United States Copyright Office, *Resale Royalties: An Updated Analysis* (Washington: USCO, 2013) at 1–2, online: <www.copyright.gov/docs/resaleroyalty/usco-resaleroyalty.pdf> [*Copyright Office Report*] (discussing the inability of visual artists to enjoy long-term success absent a *droit de suite*).

droit de suite for visual artists into their domestic legislation.[170] Several other countries, including Canada, have been considering similar arrangements.[171] In the United States the only *droit de suite* legislation was enacted in California.[172] Yet the introduction of a federal *droit de suite* as part of the *Copyright Act* has been considered on and off for decades,[173] and is ever relevant nowadays as a new *droit de suite* bill was recently introduced in the Senate.[174]

Droit de suite has always been the subject of heated debates. Briefly, its proponents emphasize the limited ability of visual artists to participate

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[170] See *Copyright Office Report*, *supra* note 169 at 8, Appendix E (indicating that more than seventy countries now have *droit de suite* legislation). For the adoption of *droit de suite* in the European Union, see EC, *Directive 2001/84/EC of the European Parliament and of the Council of 27 September 2001 on the resale right for the benefit of the author of an original work of art*, [2001] OJ, L 272/32.

[171] See *Copyright Office Report*, *supra* note 169 at 19. For the proposed *droit de suite* legislation in Canada, see Bill C-516, *An Act to amend the Copyright Act (artist's resale right)*, 1st Sess, 41st Parl, 2013 (first reading 29 May 2013), online: Parliament of Canada <www.parl.gc.ca/LegisInfo/BillDetails.aspx?Language=E&Mode=1&billId=6176239>. The Bill, proposed under the previous Parliament, suggested providing authors of artistic works with a resale royalty equal to five per cent on any sale of the work for five hundred dollars or more. The issue continues to be lobbied by various Canadian entities (see e.g. CARFAC, "Help Bring the Artists' Resale Right to Canada", online: <www.carfac.ca/initiatives/help-bring-the-artists-resale-right-to-canada/>).

[172] See Cal Civ Code § 986 (2015). Notably, the legislation's validity was the subject of litigation (see Halpern, Nard & Port, *supra* note 150 at 115–16; *Copyright Office Report*, *supra* note 69 at 20–23). A recent decision of a California District Court held it invalid and pre-empted under the Federal *Copyright Act* (see *Estate of Robert Graham v Sotheby's Inc*, 2016 WL 1464229 (CD Cal 2016)).

[173] See Toni Mione, "Resale Royalties for Visual Artists: The United States Taking Cues from Europe" (2013) 21:2 Cardozo J Int'l & Comp L 461 at 500. For the scholarly debate surrounding the introduction of *droit the suite*, see Monroe E Price, "Government Policy and Economic Security for Artists: The Case of the *Droit de Suite*" (1968) 77:7 Yale LJ 1333 at 1334–36 (maintaining that *droit de suite* is based on a romantic and unfounded myth of the starving artist); Lewis D Solomon & Linda V Gill, "Federal and State Resale Royalty Legislation: 'What Hath Art Wrought?'" (1978) 26:2 UCLA L Rev 322 at 357 (arguing that "there may be a valid need for a resale royalty in the United States" in order to adequately protect visual artists); Neil F Siegel, "The Resale Royalty Provisions of the Visual Artists Rights Act: Their History and Theory" (1988) 93:1 Dick L Rev 1 at 21 (arguing that "a resale royalty would merely establish a governmental standard for fine art"); Michael B Reddy, "The *Droit de Suite*: Why American Fine Artists Should Have a Right to a Resale Royalty" (1995) 15:3 Loy LA Ent LJ 509 at 545 (maintaining that "fundamental fairness" requires the introduction of a federal *droit de suite*); Guy A Rub, "The Unconvincing Case for Resale Royalties" (2014) 124 Yale LJ Forum, online: <yalelawjournal.org/forum/the-unconvincing-case-for-resale-royalties> (arguing that resale royalties are ineffective).

[174] US, Bill S 977, *The American Royalties Too Act of 2015*, 114th Congress, 2015 (introduced 16 April 2015).

in future markets for their works in comparison to other authors and creators,[175] and further stress that the introduction of *droit de suite* will provide such artists with a meaningful incentive.[176] Its opponents, on the other hand, suggest that a resale royalty right will hinder the operation of art markets and doubt whether such a right would actually encourage creativity in the visual arts.[177]

Examining the issue through the lens of non-linear innovation sheds light on an overlooked aspect of this debate: it clarifies that *droit de suite* can be particularly significant for artists whose works experiment in new genres, attempt to challenge existing conventions, or introduce new artistic languages. The diffusion and success of those works may be slower due to their non-linear character. Indeed, the most prominent example in the literature discussing *droit de suite* concerns Robert Rauschenberg, who in 1958 sold one of his paintings for $900, only to witness the work being resold by its owners for $85,000 fifteen years later.[178] It is perhaps not a coincidence that Rauschenberg was a groundbreaking artist, whose works prefaced the pop art movement and were certainly of a non-linear nature.[179]

The incentive provided by royalties from subsequent sales is therefore especially valuable for artists whose works step off giants' shoulders and take more time to diffuse. Highlighting this overlooked potential of *droit de suite* to counterbalance part of the non-linear innovation bias provides an additional support for its introduction into domestic copyright law.

2. Commercial Success in Patent Law

Turning to examine the treatment of slow diffusion under patent law reveals, again, a more reserved approach of this branch of law toward non-linear innovations. Patent law's impatience toward slowly diffusing innovations is manifested in the weight it ascribes to commercial success

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[175] See Solomon & Gill, *supra* note 173 at 353; Reddy, *supra* note 173 at 511–12.

[176] See Ricketson, *supra* note 169 at 412; Reddy, *supra* note 173 at 511–12; *Copyright Office Report*, *supra* note 169 at 36–39, 65 (noting that the matter is inconclusive).

[177] See *Copyright Office Report*, *supra* note 169 at 38–39, 42–45. See also Price, *supra* note 173 at 1336; Siegel, *supra* note 173 at 20–21.

[178] See e.g. *Copyright Office Report*, *supra* note 169 at 6; Mione, *supra* note 173 at 162.

[179] For a description of the groundbreaking nature of Rauschenberg's work, see e.g. Michael Kimmelman, "Robert Rauschenberg, American Artist, Dies at 82", *The New York Times* (14 May 2008), online: <www.nytimes.com/2008/05/14/arts/design/14rauschenberg.html>; "Robert Rauschenberg 1925–2008", *Tate*, online: <www.tate.org.uk/art/artists/robert-rauschenberg-1815> (indicating that Rauschenberg invented new artistic techniques and "new possibilities" that were later followed by subsequent artists).

as a proxy for nonobviousness. Nonobviousness, the most significant threshold in determining patentability, implies that the invention at stake must represent a technical advance that is not merely a trivial step forward in the state of the art.[180] Several external factors—commonly referred to as "secondary considerations"—were recognized in case law as indications for the nonobviousness of an invention.[181] One of these secondary considerations is the invention's commercial success.[182] Therefore, commercially successful inventions have higher chances to cross the nonobviousness threshold. In fact, commercial success is considered the most important secondary consideration[183] and, among commercially successful inventions, those that achieve immediate success seem to have particularly good prospects of obtaining patent protection.[184]

Numerous scholars have criticized the use of commercial success as an indication for nonobviousness. Most of these criticisms contest the inferred link between commercial success and technical advance.[185] Most

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[180] See Halpern, Nard & Port, *supra* note 150 at 228–29; Daniel Gervais & Elizabeth F Judge, *Intellectual Property: The Law in Canada*, 2nd ed (Toronto: Thomson Carswell, 2011) at 735–37.

[181] See *Graham v John Deere Co of Kansas City*, 383 US 1 at 17–18, 86 S Ct 684 (1966). For a discussion of the secondary considerations, see generally Jonathan J Darrow, "Secondary Considerations: A Structured Framework for Patent Analysis" (2010/2011) 74:1 Alb L Rev 47; Natalie A Thomas, "Secondary Considerations in Nonobviousness Analysis: The Use of Objective Indicia Following *KSR v. Teleflex*" (2011) 86:6 NYUL Rev 2070 at 2107–08 (maintaining that the role of secondary considerations in determining nonobviousness should increase after the recent Supreme Court decision in the *KSR* case).

[182] See Halpern, Nard & Port, *supra* note 150 at 234; Gervais & Judge, *supra* note 180 at 741.

[183] See Robert P Merges, "Commercial Success and Patent Standards: Economic Perspectives on Innovation" (1988) 76:4 Cal L Rev 803 at 823 (observing that commercial success has become a "decisive" factor in determining patentability).

[184] See e.g. the US cases of *Bayer AG v Carlsbad Technology Inc*, 2001 WL 34125673 (SD Cal 2001) at 7 (the immediate success of a top-selling drug regarded as an indication of nonobviousness); *Henkel Corp v Coral Inc*, 754 F Supp 1280, 21 USPQ (2d) 1081 (ND Ill 1990) at 1307 (the fact that the product "spread like wildfire" indicates nonobviousness). See also the Canadian case of *Wessel v Energy Rentals Inc*, 2004 FC 791 at paras 22–23, 32 CPR (4th) 315 (the invention's "immediate commercial success" is a proxy for its nonobviousness).

[185] See e.g. Richard L Robbins, "Subtests of 'Nonobviousness': A Nontechnical Approach to Patent Validity" (1964) 112:8 U Pa L Rev 1169 at 1175–77 (highlighting various market conditions and product attributes that may lead to success and do not support nonobviousness); Edmund W Kitch, "Graham v. John Deere Co.: New Standards for Patents" (1966) 1966 Sup Ct Rev 293 at 301–03 (arguing that the link between nonobviousness and commercial success involves a set of inferences that are weak and unconvincing); Merges, *supra* note 183 at 859 (arguing that "commercial success is a poor indicator of significant technical advance"); Shur-Ofry, "Complexity", *supra* note 102 at 67–73 (rely-

notable for our purposes is Samuel Oddi's observation that the test disfavours "revolutionary inventions" that are slower to achieve commercial success.[186] Although Oddi's notion of revolutionary inventions does not completely overlap with this article's concept of non-linear innovation,[187] his insight is certainly valid with respect to the latter. Favouring commercially successful inventions—and particularly inventions that obtain immediate success—overlooks the slower rate of diffusion that characterizes non-linear innovations. Hence, a patent law doctrine that regards commercial success as a proxy for nonobviousness favours incremental innovation and enhances the non-linear innovation bias. Facilitating non-linear innovation, then, lends further support to the view that commercial success should cease to serve as a valid indicator for nonobviousness.[188]

D. Targeted De-Biasing Mechanisms: Identifying Non-Linear Innovations

Finally, can the intellectual property system—particularly patent law—more accurately identify non-linear innovations and provide them with targeted de-biasing mechanisms?[189] Although several scholars addressed the need to encourage "more difficult",[190] "revolutionary",[191] "a-

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ing on complexity theory to highlight the non-linear relations between success and non-obviousness).

186 Oddi, *supra* note 162 at 1126.

187 Oddi's definition emphasizes the ex post impact of these inventions and not their deviation from previous conventions. See *ibid* at 1115 (referring to "revolutionary inventions" as those "which produce genuine revolutions in consumption or production ... [and] make significant differences in the efficiency of production or the quality of life"). He therefore attributes the slower diffusion of revolutionary inventions mostly to lack of established production and marketing channels (see *ibid* at 1126–27).

188 Notably, the insights concerning the slow diffusion of non-linear innovation may carry implications for additional intellectual property doctrines that are time sensitive, such as the validity of post-expiration payments in intellectual property licenses and, possibly, the term of intellectual property protection itself. This article neither investigates nor prescribes any recommendations on these complex topics and their exploration through the lens of non-linear innovation will be left for future research.

189 The discussion in this sub-part focuses on patent law and not on copyright law for two reasons. First, patent law sets a higher protection threshold, in comparison to copyright's originality threshold, which most works—linear and non-linear—can easily cross (see Christopher Buccafusco et al, "Experimental Tests of Intellectual Property Laws' Creativity Thresholds" (2014) 92:7 Tex L Rev 1921 (discussing the different protection thresholds in patent and copyright law)). A second reason is the availability of ample relevant data from network analyses of patent citation networks (see *infra* notes 194–218 and accompanying text).

190 Michael J Meurer & Katherine J Strandburg, "Patent Carrots and Sticks: A Model of Nonobviousness" (2008) 12:2 Lewis & Clerk L Rev 547 at 551 (arguing that the patent system should incentivize researchers to produce more difficult research projects).

typical",[192] or "pioneering"[193] inventions, the question of how to identify such inventions remains largely unanswered in legal scholarship. Thus, some non-linear innovations may not be instantly recognized as such, and may even encounter difficulties in crossing the patentability threshold. Indeed, Sean Seymore recently observed that patent applications which represent scientific breakthroughs may be denied patent protection due to patent examiners' lock-in in prevalent scientific conventions.[194]

However, research in economics and business management that has explored similar questions can provide some important guidance on identifying non-linear innovation.[195] This literature is comprised of numerous studies that used network analysis to empirically investigate the traits of "breakthrough" or "radical" inventions.[196] They define radical or breakthrough inventions as foundational inventions that form the basis of many subsequent technological developments and, in light of this definition, identify patents representing "radical inventions" as those patents that have the largest number of subsequent citations by following patents.[197] This definition is largely consistent with this article's insights about the potentially broad impact of non-linear innovations as platforms for many subsequent inventions and is therefore useful for our purposes.[198]

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191 Oddi, *supra* note 162 at 1128 (proposing a special type of protection for "revolutionary patents").

192 Seymore, "Atypical Inventions", *supra* note 13 at 2062 (proposing a different examination standard for "atypical" inventions).

193 John R Thomas, "The Questions Concerning Patent Law and Pioneer Inventions" (1995) 10:1 High Tech LJ 35 (discussing the extended protection afforded to pioneering inventions).

194 Seymore, "Atypical Inventions", *supra* note 13 at 2078–79.

195 See e.g. Trajtenberg, *supra* note 10; Lee Fleming, "Recombinant Uncertainty in Technological Search" (2001) 47:1 Management Science 117 at 130; Dahlin & Behrens, *supra* note 10 at 717–24; Arts & Veugelers, *supra* note 52; Ahuja & Lampert, *supra* note 52; Schoenmakers & Duysters, *supra* note 10 at 1052–53. For a detailed discussion of this literature, see *infra* notes 195–218 and accompanying text.

196 See the literature cited in *supra* note 195.

197 See e.g. Trajtenberg, *supra* note 10 at 184; Fleming, *supra* note 195 at 122; Arts & Veugelers, *supra* note 52 at 1–3; Ahuja & Lampert, *supra* note 52 at 523; Abrams, Akcigit & Popadak, *supra* note 52 at 9.

198 See *supra* notes 52–54 and accompanying text. Notably, the definition used in the economic literature does not capture all non-linear innovations. First, success itself is not a linear process and there may certainly be non-linear inventions that neither attain significant success nor a large number of subsequent citations (see Shur-Ofry, "Complexity", *supra* note 102 at 67–73). In addition, patents may be cited for reasons that do not necessarily reflect reliance by subsequent inventions. Yet, the methodology of the eco-

This body of literature, combined with this article's foregoing analysis of the traits of non-linear innovations, yields two important insights. The first concerns the prior art cited by breakthrough inventions.[199] The aforesaid literature shows that, contrary to views expressed by courts and scholars, a paucity of prior art is *not* a sine qua non indicator for non-linear innovation.[200] Radical inventions are not devoid of prior art, but actually include no less prior art than other, non-radical, inventions.[201] These findings are consistent with our preceding analysis that non-linear innovations do not emerge in a vacuum but develop against a background of solid knowledge and familiarity with scientific domains.[202] Furthermore, while these innovations alter some of the basic foundations or methods of a domain, they still preserve many of its concrete past achievements.[203] Therefore, there is no reason to assume that inventions reflecting such shifts shall be detached from prior art. The empirical studies indeed imply that "already existing knowledge seems of paramount importance" for breakthrough inventions,[204] and reinforce one of this arti-

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nomic studies still captures those innovations that ex post did serve as a basis for many subsequent inventions. Therefore, it can provide us with an ex ante notion about the traits of such innovations.

199 The term "prior art" refers to previous patents or scientific publications pertaining to the invention that are cited in the patent application. See Arts & Veugelers, *supra* note 52 at 4 (examining prior art in breakthrough patents in the biotechnology field). See also Schoenmakers & Duysters, *supra* note 10 at 1051, 1057 (examining prior art in radical patents "selected from a pool of more than 300,000 patents").

200 For case law and scholarship that regards paucity of prior art as an indication for the "pioneering" or "breakthrough" nature of an invention, see *Texas Instruments v United States International Trade Commission*, 805 F (2d) 1558 at 1572, 231 USPQ 833 (Fed Cir 1986) (referring to pioneering inventions as "devoid of prior art"). See also Anthony H Azure, "*Festo*'s Effect on After-Arising Technology and the Doctrine of Equivalents" (2001) 76:4 Wash L Rev 1153 at 1164 (arguing that "[b]road literal claims can be written for pioneer inventions because, by definition, pioneer inventions are not restricted by prior art"); Brian J Love, "Interring the Pioneer Invention Doctrine" (2012) 90:2 NCL Rev 379 at 384 (arguing that "[b]y definition, pioneer inventions arise in fields with limited prior art"), 417 (maintaining that drafting patent applications for pioneering inventions is easier when there is no prior art); Thomas, *supra* note 193 at 57 ("the paucity of prior art was, if anything, the forerunner of a smooth prosecution despite the sweeping claims generally found in these patents").

201 See Schoenmakers & Duysters, *supra* note 10 at 1057 (concluding that radical inventions "are to a higher degree based on existing knowledge than non-radical inventions"); Arts & Veugelers, *supra* note 52 at 21 ("we find biotech breakthroughs to build substantially on prior art").

202 See *supra* notes 117–22 and accompanying text.

203 See Kuhn, *supra* note 9 at 168 ("the new paradigm must promise to preserve a relatively large part of the concrete problem-solving ability that has accrued to science through its predecessors").

204 Schoenmakers & Duysters, *supra* note 10 at 1057.

cle's contentions: non-linear and incremental innovations are complementary, not dichotomous.

Second, the aforesaid studies indicate that non-linear inventions often include new combinations of already existing knowledge. While the notion that new recombinations are an ultimate source of novelty can be traced back to the writings of Joseph Schumpeter,[205] this more recent line of research provides it with empirical support by demonstrating that patents representing breakthroughs are more likely to recombine technological components not previously combined.[206] This conclusion is derived from examining the "technological building blocks" of those patents as reflected by the prior art they cite and by their classification into various technological subclasses.[207] More specifically, the findings indicate that patents representing radical inventions are more likely to cite new combinations of prior art.[208] In addition, these patents are more likely to be classified into various technological subclasses that infrequently appear together in a single patent.[209]

At least two patent law doctrines can benefit from this understanding and adapt to more accurately identify non-linear innovations. The first is the nonobviousness requirement. The second is the doctrine of pioneering inventions.

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[205] Joseph Schumpeter, *Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalist Process*, vol 1, 1st ed (New York: McGraw-Hill Book Company, 1939) at 88 ("innovation combines factors in a new way").

[206] See Arts & Veugelers, *supra* note 52 at 21 ("[b]reakthroughs ... are more likely to combine technological components"); Fleming, *supra* note 195 at 130 ("the source of technological novelty and uncertainty lies within the combination of new components and new configurations of previously combined components").

[207] US Patent Offices assign each patent to one of multiple pre-defined subclasses in accordance with its technological characteristics. There are currently more than 150,000 subclasses. See US, United States Patent and Trademark Office, *Overview of the US Patent Classification System (USPC)*, 2012, online: <www.uspto.gov/patents/resources/classification/overview.pdf>. See also WIPO, "International Patent Classification (IPC)", online: <www.wipo.int/classifications/ipc/en>; Fleming, *supra* note 195 at 122–23 (explaining that the study of the invention classifications can serve as a proxy for the patent's technological "building blocks").

[208] See Dahlin & Behrens, *supra* note 10 at 725–27, 732 (showing that patents protecting technologically radical inventions have a dissimilar set of prior art citations compared to previous patents filed in the same field); Arts & Veugelers, *supra* note 52 at 16 (indicating that "breakthrough inventions seem to use prior art from many different technology fields, particularly technology fields different from its own technology fields").

[209] See Fleming, *supra* note 195 at 130 (concluding that technological breakthroughs derive from new combinations of "well-used information or components").

1. Patent's Nonobviousness Threshold

The foregoing discussion illuminates the significance of new combinations as a proxy for non-linear innovation.[210] Can patent law take this trait into account when determining nonobviousness?[211] To a certain extent, patent law's doctrine of analogous art reflects a similar insight.[212] The doctrine provides that the assessment of the prior art, against which nonobviousness is measured, should take into account only prior art that is "analogous". Prior art that is "too remote" from the invention is considered non-analogous and cannot support a rejection of patentability due to obviousness. The determination whether a specific prior art reference constitutes analogous or non-analogous art depends to a large extent on that reference's "field of endeavor" and its proximity to the field of the invention.[213] References from a different field are more likely to be considered non-analogous and therefore are less likely to form an obstacle to patentability.[214] As non-linear inventions are more likely to combine prior art from diverse technological fields, they will more easily overcome analogous art objections and cross the nonobviousness threshold.

The traditional justification for the analogous art test is the difficulties inventors face to gain access to prior art outside of their own field.[215] With the increased access and search mechanisms of the digital era, this rationale, and the doctrine in general, were criticized as "outdated"[216] and "outmoded".[217] Yet the foregoing analysis indicates that the ability to link prior art from diverse fields is not just a matter of "access" and "aware-

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[210] See *supra* notes 205–08 and accompanying text.

[211] For patent law's nonobviousness requirement, see *supra* note 180 and accompanying text.

[212] For patent law's doctrine of analogous art, see generally Halpern, Nard & Port, *supra* note 150 at 229–30.

[213] For prominent US case law introducing and implementing this test, see *In re Clay*, 966 F (2d) 656 at 658–59, 23 USPQ (2d) 1058 (Fed Cir 1992) [*Clay*]; *Innovention Toys, LLC v MGA Entertainment, Inc*, 637 F (3d) 1314 at 1321, 98 USPQ (2d) 1013 (Fed Cir 2011). For a detailed review of the development of the analogous art test, see Simon, *supra* note 112 at 30–44.

[214] See *Clay*, *supra* note 213 at 658–59 (noting that references from a different field of endeavor may still be considered analogous if "reasonably pertinent to the particular problem with which the inventor is involved"); Halpern, Nard & Port, *supra* note 150 at 229.

[215] See Halpern, Nard & Port, *supra* note 150 at 229 ("it is not only unfair but also unrealistic to require an inventor to be presumptively aware of non-analogous prior art").

[216] Simon, *supra* note 112 at 44.

[217] *Ibid* at 29.

ness", but requires problem finding creativity that is far from trivial.[218] The lens of non-linear innovation, then, highlights the potential of the analogous art doctrine to facilitate patent protection for non-linear inventions and provides it with a stronger, more solid justification.

Moreover, and importantly, the above analysis indicates that the significance of new recombinations—either in the prior art cited in the patent application or in its Patent and Trademark Office subclasses—should extend beyond the analogous art doctrine. The accumulating evidence that diverse and infrequent combinations are a reliable proxy for radical inventions is substantial, and the use of new combinations as a proxy for scientific novelty is becoming acceptable among researchers in various fields.[219] Patent law, too, should actively take this factor into account in its nonobviousness analysis, rather than consider it merely as a shield against obviousness rejections.

In other words, if patent law is to facilitate non-linear inventions, it should give *independent weight* to the existence of new and infrequent recombinations in the prior art or in the subclasses of an invention and regard them as *positive* indications for the invention's nonobviousness. In light of the "expansive and flexible approach" toward obviousness analysis which was adopted by the US Supreme Court in the matter of *KSR* and the "broad inquiry" instructed by that Court,[220] it seems that current patent law can easily accommodate such factors into its nonobviousness evaluation.[221]

2. Pioneering Inventions

In addition to its implications for the question of nonobviousness, the above analysis sheds some light on the doctrine of pioneering inventions. This common law doctrine is perhaps the most direct attempt on the part of patent law to distinguish "pioneering" from "other" technologies. Most prominently, it provides the former with broader protection against in-

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[218] See the discussion in Part I, above. *Cf* Simon, *supra* note 112 at 39 (maintaining that improved access to information does not mean appreciating its significance).

[219] See e.g. Boudreau et al, *supra* note 76 at 3 (measuring the novelty of research proposals by the prevalence of "unique combinations of descriptive knowledge keywords" in the medical field ("MeSH terms") "that had not previously appeared in the published medical sciences literature"); Uzzi et al, *supra* note 78 at 468 (using the frequency of combinations of references in academic papers to evaluate novelty of academic works).

[220] *KSR International v Teleflex Inc*, 550 US 398 at 415, 127 S Ct 1727 at 1739 (2007).

[221] On the more technical and practical level, patent offices should facilitate the ability of examiners, courts, and parties to access and identify new recombinations through their databases.

fringement under the doctrine of equivalents.[222] This protection implies that owners of patents representing pioneering inventions can more easily succeed in an infringement claim, even where their patent claims are not literally infringed.[223] Yet, more than a century after its introduction, the justifications for the doctrine of pioneering inventions are still controversial[224] and the question of what qualifies as a pioneering invention remains highly uncertain.[225]

Assessing the pioneering invention doctrine through the prism of non-linear innovation raises a difficult question: does the doctrine serve as a de-biasing mechanism, which sets off some of the difficulties faced by non-linear innovators, or does it afford already successful inventions with an extra, undeserved protection?[226] While a complete examination of this question is beyond the scope of this article, the present discussion does offer some guidance in calibrating the doctrine toward the former aim.

First, our analysis provides some support to one of the common justifications for the doctrine of pioneering inventions—that drafting patent applications for pioneer patents is "a difficult task because of the new scientific ground being broken by the ... invention."[227] Paradigm shifts and problem finding creativity are analogous to creating a new language.[228] It is thus entirely plausible that the first expressions—in our case, in the form of patent claims and specifications—in such a new language would be more difficult to accurately phrase in relation to subsequent ones. The empirical evidence discussed above further suggests that non-linear innovations cite as much prior art as cumulative inventions.[229] These insights

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222 See generally Thomas, *supra* note 193; Love, *supra* note 200; Azure, *supra* note 200.

223 See e.g. Love, *supra* note 200 at 382–83, 389–97 (explaining the broader patent scope under the doctrine).

224 See e.g. *ibid* at 384 (maintaining that the doctrine should be "interred"); Oddi, *supra* note 162 at 1115 (proposing to provide a "special incentive" for "revolutionary inventions"); Dan L Burk & Mark A Lemley, "Biotechnology's Uncertainty Principle" (2004) 54:3 Case W Res L Rev 691 at 738 (arguing that the doctrine can play a role in providing appropriate incentives in the biotech field); Azure, *supra* note 200 at 1166 (regarding the doctrine as a "necessary incentive").

225 See e.g. Thomas, *supra* note 193 at 59 (indicating that the question of how patent law distinguishes "those favored few inventions from the remainder" is unclear).

226 For the latter view, see e.g. Love, *supra* note 200 at 384 (maintaining that pioneers use their patents to impede the progress of other technologies and arguing that the doctrine should be "interred").

227 *Moore v United States*, 211 USPQ 801 at 806, 1981 WL 66976 (Ct Cl Trial Div).

228 See *supra* note 49 and accompanying text.

229 See *supra* notes 195–200 and accompanying text.

cast doubt on scholarly contentions that drafting pioneering patent applications is actually simpler due to paucity of prior art.[230]

In addition, the foregoing analyses can provide some normative guidance in determining what constitutes a pioneering invention—a question that yielded multiple answers on the part of courts.[231] First, the findings that such inventions are not devoid of prior art but contain as much prior art as cumulative and linear inventions[232] imply that a paucity of prior art should *not* serve as a prerequisite for regarding an invention as "pioneering".[233] In addition, the findings that novel combinations in the prior art or in the subclasses of an invention constitute a proxy for its breakthrough nature can provide a measurable and viable indication for an invention's pioneering nature.[234] The new combinations factor is certainly more accurate and preferable to existing tests that focus on the ex post "impact" or "success" of an invention as a proxy for a "pioneering" character.[235] Overall, calibrating the doctrine of pioneering inventions to reflect our increasing understanding of the nature of breakthrough inventions may inject it with some measure of objectivity and facilitate the inclusion of non-linear innovations within its ambit.

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Scrutinizing patent and copyright law through the lens of non-linear innovation reveals that some intellectual property doctrines, particularly in the field of copyright, are more receptive toward non-linear innovations, while others demonstrate strong preference toward the linear and incremental. The analysis in this Part further demonstrates that intellectual property law can adapt to better foster non-linear innovations and

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230 See *supra* note 200.

231 In 1898, the US Supreme Court in *Boyden Power-Brake Co v Westinghouse*, 18 S Ct 707 at 718, 170 US 537 (1898) defined a pioneering invention as an invention that achieves "a function never before performed, a wholly novel device, or one of such novelty and importance as to mark a distinct step in the progress of the art, as distinguished from a mere improvement or perfection of what had gone before." Subsequent decisions referred to inventions that embody a "broad breakthrough", "basic operational concept", "major advance", are "broadly new", or are "devoid of significant prior art" (Thomas, *supra* note 193 at 45–52).

232 See *supra* notes 195–200.

233 For case law and scholarship that regards paucity of prior art as an indication for the "pioneering" nature of an invention, see *supra* note 200.

234 See *supra* notes 205–19 and accompanying text.

235 See *supra* note 198. In this context, too, feasibility of actually using the new-combinations factor would depend to a large extent on the technical ability of examiners, courts, and parties to access and identify new recombinations through the PTO database.

encourage those who wish to step off giants' shoulders. While the recommendations set forth above are illustrative of the role that intellectual property law can play in this context, they are far from exhaustive.[236] The review of additional branches and doctrines of intellectual property through the prism of non-linear innovation is certainly warranted and deserves further investigation.

Interestingly, the preceding analysis demonstrates that promoting non-linear innovation does not prescribe a uniform approach—whether minimalist or maximalist—toward the scope of intellectual property protection.[237] Rather, in certain circumstances (for example, in the case of patent law's experimental use exception) this task supports broader exceptions to existing intellectual property rights. In other instances (for example, in the case of *droit de suite*) it may point toward a certain expansion of these rights, while in yet other cases (for example, with regard to patent law's nonobviousness test) it warrants a nuanced fine-tuning of extant doctrines that is neither expansive nor restrictive.

Lastly, beyond specific doctrinal changes, fostering non-linear innovation may also require a certain adjustment in intellectual property theory and discourse. The following, final Part of this article takes a closer look at this proposition.

IV. Beyond Intellectual Property Doctrine: De-Romanticizing the Giants

Our discussion began with the contemporary focus of intellectual property theory on the cumulative and incremental nature of innovation and creation.[238] To a certain extent, this focus has emerged as a counter-reaction to the notion of the "romantic author" that dominated intellectual

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236 For additional relevant proposals in recent literature, see Seymore, "Atypical Inventions", *supra* note 13 at 2078–88 (suggesting that the "enablement", rather than "operability", requirement should be used by patent examiners in order to distinguish breakthrough inventions, which should be afforded patent protection, from "truly impossible inventions", which should not). See also Pedraza-Fariña, *supra* note 13 at 858–61 (arguing that the nonobviousness test should incorporate the social dimension of "unconventional lines of research," and take into account prior art that has "taught away" from the invention as an indication for nonobviousness).

237 For the minimalist-maximalist divide in intellectual property scholarship, see e.g. Barton Beebe, "Search and Persuasion in Trademark Law" (2005) 103:8 Mich L Rev 2020 at 2051–52 (criticizing this divide in trademark law); Abraham Drassinower, "A Note on Incentives, Rights, and the Public Domain in Copyright Law" (2011) 86:5 Notre Dame L Rev 1869 (observing this divide in copyright law); Alan Devlin, "Systemic Bias in Patent Law" (2011) 61:1 DePaul L Rev 57 (making similar observations with respect to patents); Shur-Ofry, "Complexity", *supra* note 102 at 61 (criticizing the uniform approach toward the scope of intellectual property protection).

238 See *supra* note 6 and accompanying text.

thought in the nineteenth century, and perceived authors and inventors as lone and isolated geniuses.[239] A prominent strand in current intellectual property literature thus warns against romanticizing authors and inventors and emphasizes that affording intellectual property owners broad control over their works and inventions may entail high social costs.[240]

As part of this discourse, intellectual property scholarship has embraced with much enthusiasm the dwarfs on the shoulders of giants metaphor, the ultimate image of the reliance of all authors and inventors on the works and inventions of their predecessors. In fact, the dwarfs-and-giants aphorism appears in hundreds of intellectual property articles from the recent decades,[241] and has become a most prevalent meme in the field of intellectual property.[242]

This article suggests that neither the "lone genius" nor the "shoulders of giants" metaphor accurately captures the dynamics of non-linear innovation. On the one hand, such innovation is characterized by dissent and discontinuity and, hence, does not fit the shoulders of giants paradigm. At the same time, non-linear innovation does not emerge from a "clean slate" and is not detached from all previous works and knowledge as presumed by the "sole genius" narrative. In other words, current intellectual property theory fails to properly accommodate non-linear innovation. And this failure comes with a cost. First, as the preceding Part demonstrates, various intellectual property doctrines are not adequately tailored to promote non-linear innovation. But no less importantly, the prevalence of the dwarfs-and-giants metaphor in intellectual property discourse, together with the general theoretical disregard for non-linear innovation, may result in a certain paradox. Adopting a view of progress that concentrates

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239 For prominent writing introducing and criticizing the concept of romantic authorship, see e.g. Martha Woodmansee, "The Genius and the Copyright: Economic and Legal Conditions of the Emergence of the 'Author'" (1984) 17:4 American Society for Eighteenth-Century Studies 425 [Woodmansee, "The Genius"]; James DA Boyle, "The Search for an Author: Shakespeare and the Framers" (1988) 37:3 Am UL Rev 625; Peter Jaszi, "Toward a Theory of Copyright: The Metamorphoses of 'Authorship'" (1991) 1991:2 Duke LJ 455; Martha Woodmansee, "On the Author Effect: Recovering Collectivity" (1992) 10:2 Cardozo Arts & Ent LJ 279 [Woodmansee, "Author Effect"]; Litman, *supra* note 6; Mark A Lemley, "The Myth of the Sole Inventor" (2012) 110:5 Mich L Rev 709 at 710 (arguing that patent law is built around "[t]he canonical story of the lone genius inventor" which "is largely a myth").

240 See e.g. Woodmansee, "The Genius", *supra* note 239 at 426–31; Boyle, *supra* note 239 at 626–31, 633–36, 642–43; Jaszi, *supra* note 239 at 455–64; Woodmansee, "Author Effect", *supra* note 239 at 279–80, 291–92; Lemley, *supra* note 239 at 710–33, 736–45, 760.

241 A quick search of the phrase "shoulders of giants" in Westlaw's law reviews database yields 650 results (last checked: May 2016).

242 See *supra* notes 6–8 and accompanying text.

solely on the cumulative and incremental creates a feedback loop that further buttresses the myth of science and creativity as strictly linear, cumulative processes.[243] Furthermore, such an exclusive focus reinforces the image of the "giants" as arbiters and sole sources of intellectual authority.[244] This, in turn, may hinder those who wish to dispute this authority and step off their shoulders. In an attempt to de-romanticize the authors, then, we may be romanticizing the giants.

To some extent, this latter insight is supported by research investigating the link between creativity and culturally embedded factors. This scholarship implies that overemphasis on authority and convention may be negatively correlated with creativity and with the ability to part with existing paradigms. In other words, cultures that attribute much weight to authority, conservatism, and convention are more likely to discourage discontinuity and contradiction.[245] On the other hand, less authoritarian cultures that provide a more receptive environment for dissent and contradiction may be more likely to encourage paradigm shifting creativity.[246] Interestingly, Kuhn's work itself may have had such a cultural effect: by coining the phrase "paradigm shift", and by explicitly highlighting various changes in scientific paradigms, *The Structure* allegedly increased the awareness of such shifts and facilitated their reception.[247]

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[243] See the discussion in Parts I and II, above. See also Cristie Ford, *Flexible Regulation and Financial Crisis: Innovation as Risk* (Cambridge University Press), ch 7 [forthcoming in 2016] (discussing regulatory policy for sedimentary (incremental) innovation and observing that "we ... have a romantic account of sedimentary innovation, just as we have a romantic account of seismic [radical] innovation").

[244] See Merton, *supra* note 7 at 99–100 (discussing the inclination to perceive the "moderns" as "dwarfs" and the "ancients" as "giants", which implies that "intellectual authority is only supplied by ancient lineage"); Margaret Chon, "The Romantic Collective Author" (2012) 14:4 Vand J Ent & Tech L 829 at 840–41 (arguing that the notion of the romantic author as an "arbiter" was transferred to collective works in digital environments whose authors are often anonymous and unaccountable).

[245] See e.g. Calvin W Taylor & Frank Barron, eds, *Scientific Creativity: Its Recognition and Development* (New York: John Wiley & Sons, 1966) at 152 (arguing that creative societies have a "lack of fear of dissent and contradiction" and "a willingness to break with custom"); Sawyer, *supra* note 11 at 276–80 (indicating that some cultures provide incentive to continuity while others provide incentive to change); David Yau Fai Ho & Rainbow Tin Hung Ho, "Knowledge Is a Dangerous Thing: Authority Relations, Ideological Conservatism, and Creativity in Confucian-Heritage Cultures" (2008) 38:1 J Theory Social Behaviour 67 at 68, 80–83 (maintaining that rigidly hierarchical and authoritarian cultures discourage creativity).

[246] See e.g. Taylor & Barron, *supra* note 245 at 152; Sawyer, *supra* note 11 at 276–80; Fai Ho & Hung Ho, *supra* note 245 at 68, 80–83.

[247] See e.g. Stella Vosniadou, Aristides Baltas & Xenia Vamvakoussi, eds, *Re-Framing the Conceptual Change Approach in Learning and Instruction* (Amsterdam: Elsevier, 2007) at 1–2 (investigating the impact of Kuhn's theory and maintaining that awareness

Intellectual property theory is also part of our cultural ecosystem and its underlying message about the nature of innovation and creation may have a similar impact. Therefore, depicting a fuller picture of innovation in intellectual property discourse is itself valuable. Our analysis, then, calls for expanding intellectual property theory to accommodate the more complex and nuanced realities of innovation dynamics. Alongside the important and continuing discussion of incremental and cumulative innovation, intellectual property should make room for the complementary narrative of non-linear innovation. By recognizing more than a single narrative of progress, and by tuning its doctrinal tools accordingly, intellectual property theory can play an important role in mitigating the "giants effect" and fostering non-linear innovation.

Conclusion

This article began with the story of Dan Shechtman that sparked my interest in non-linear innovation. It concludes with the words of Sven Lidin, who delivered Shechtman's Nobel presentation speech in 2011:

> Coming down from the shoulders of the giant is a challenge. Not least because those that remain aloft are tempted to look down at those on the ground. ... It is far too easy for all of us to remain in our lofty positions, and with lofty disdain regard the fool who claims that we are all wrong. To be that fool on the ground takes great courage, and both [Shechtman] and those that spoke out on his behalf deserve great respect.[248]

Shechtman's courage was rare. The hostility he encountered was not. The discussion in this article indicates that many authors and inventors who step off giants' shoulders face similar resistance.

This article demonstrates that intellectual property law can play a role in mitigating the non-linear innovation bias and in encouraging non-linear innovation. It sets forth a series of proposals for adjustments to extant intellectual property doctrines—from patent law's nonobviousness test to copyright's *droit de suite*—that would better calibrate intellectual property law toward this type of innovation. On a more fundamental, theoretical level, it clarifies that non-linear innovation is part of the story of progress in the domains of science and art. Such progress does not stand in contrast to cumulative progress, but rather complements it. Embedding non-linear innovation in intellectual property theory and doctrine, alongside cumulative innovation, would base intellectual property law on a

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might induce conceptual change). *Cf* Schulz, *supra* note 59 at 125–27, 167 (highlighting Kuhn's contribution to cultural understanding that paradigms are not infallible).

248 Lidin, *supra* note 5.

more complete and accurate narrative of progress and would make a positive contribution to our cultural ecosystem of innovation and creation.