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THE FRACTAL GEOMETRY OF INVENTION

ALAN L. DURHAM*

Abstract: Fractals are geometric objects of inexhaustible detail. Fractal structures have been found in the contours of mountain ranges, the patterns of veins on a leaf, and the fluctuations of the Dow Jones Industrial Average. The endeavor of inventing new technologies, consisting of a hierarchical network of practical inquiries, exhibits fractal properties as well. Among these are multiplicity, latency, and self-similarity. Multiplicity means that a single inventive idea may lead to an immense and diverse array of technological artifacts. Latency means that the potential of an inventive idea to yield practical embodiments only reveals itself in time, and may never be fully known. Self-similarity means that invention is not scale-dependent; in other words, breakthroughs and refinements may be difficult, in principle, to distinguish. Invention, as a whole, resembles an ever-expanding fractal island of promontory upon promontory. Patent law assigns a particular inventor legal rights to a portion of that intricate coastline. The fractal properties of multiplicity, latency, and self-similarity contribute to many of the perennial difficulties in patent law, including fixing the meaning of claim language, properly applying the enablement and written description requirements, and identifying “abstract ideas” that cannot be patented. Understanding the fractal properties of invention is an important step in addressing these issues.

INTRODUCTION

A fundamental question in patent-related disputes is, “What did the patentee (or patent applicant) invent?”¹ The claims of the patent define the invention, in so far as “the invention” means the sphere of activity reserved exclusively to the patentee.² The disclosures of the pa-

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¹ See *Diamond v. Diehr*, 450 U.S. 175, 193–94 (1981) (Stevens, J., dissenting) (“The starting point in the proper adjudication of patent litigation is an understanding of what the inventor claims to have discovered.”); *In re Grams*, 888 F.2d 835, 839 (Fed. Cir. 1989) (“In all instances, this critical question must be answered: ‘What did applicants invent?’”).

² See *Phillips v. AWH Corp.*, 415 F.3d 1303, 1312 (Fed. Cir. 2005) (en banc) (“It is a ‘bedrock principle’ of patent law that ‘the claims of a patent define the invention to which

tent specification describe and enable the invention, in so far as “the invention” means the patentee’s substantive contribution to the art.³ Before it can be claimed or described, “the invention” begins as an idea formed in the mind of the inventor.⁴ In a perfect world, a world in which the patent system operated as a smooth-running and well-regulated machine, “the invention” would be a single thing—one thing conceived, reduced to practice, disclosed, and claimed. The reality is more complicated, and the multi-faceted nature of “the invention” in our world is the source of much tension, friction, and potential mishaps. Partly this is a problem of communication. As the U.S. Supreme Court has observed, the shortcomings of vocabulary produce “idea gaps” when one translates a conception into the language of a claim.⁵ Similar problems may impair the completeness of the patent disclosure. This Article suggests, however, that the source of the difficulty in pinning down “the invention” is even more fundamental, and begins in the nature of invention itself.

Few inventions are singular entities, unconnected to broader networks of technological advancement.⁶ Most inventions are variations on what has come before and have the potential to generate further variations or refinements.⁷ Whether it is the work of an individual researcher or the community of all researchers, invention is a complex web of questions and answers. Each insight may suggest a host of new paths to follow in the search for technological solutions to the needs of mankind. One might visualize invention as an ever-expanding island,

the patentee is entitled the right to exclude.” (citations omitted) (quoting *Innova/Pure Water, Inc. v. Safari Water Filtration Sys., Inc.*, 381 F.3d 1111, 1115 (Fed. Cir. 2004))); see also Jeffrey A Lefstin, *The Formal Structure of Patent Law and the Limits of Enablement*, 23 BERKELEY TECH. L.J. 1141, 1145 (2008) (“In modern parlance, the claim, ‘the invention,’ and ‘the patent’ are essentially synonymous.”).

³ See 35 U.S.C. § 112, para. 1 (2006), amended by Leahy-Smith America Invents Act, Pub. L. No. 112-29, § 4(c), (e), 125 Stat. 284, 296–97 (2011) (effective Sept. 16, 2012) (“The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, . . . to make and use the same . . .”).

⁴ See *Pfaff v. Wells Elecs., Inc.*, 525 U.S. 55, 60 (1998) (“The primary meaning of the word ‘invention’ in the Patent Act unquestionably refers to the inventor’s conception . . .”).

⁵ See *Festo Corp. v. Shoketsu Kinzoku Kogyo Kabushiki Co.*, 535 U.S. 722, 731 (2002) (quoting *Autogiro Co. of Am. v. United States*, 384 F.2d 391, 397 (Cl. Ct. 1967)) (“A verbal portrayal is usually an afterthought written to satisfy the requirements of patent law. This conversion of machine to words allows for unintended idea gaps which cannot be satisfactorily filled.”).

⁶ See GEORGE BASALLA, *THE EVOLUTION OF TECHNOLOGY* 208–09 (1988) (stating that “every novel artifact has an antecedent” and is “related to what has been made before”).

⁷ See *id.*

each advancement pushing out a new headland, itself the root of newer promontories, each generation mirroring the last, ad infinitum.

A mathematician would recognize that island as a Koch island—a species of fractal.⁸ A fractal is a geometric figure of inexhaustible detail.⁹ The closer one examines a fractal, the more detail one finds.¹⁰ Structures with fractal properties can be found in nature—in the contours of an actual island, for example.¹¹ A map might approximate the shape of the island, but would inevitably miss twists and turns too small to be depicted.¹² A larger scale map could correct those deficiencies, but only up to a point.¹³ Closer examination of a coastline always reveals more detail—twists upon twists, turns upon turns.¹⁴

Certain properties are typical of fractals, and the real-world objects that mimic them. One of these properties I call “multiplicity,” in reference to that inexhaustible supply of detail. A second property I call “latency,” in reference to the fact that the fractal details reveal themselves only on examination—an examination that can never be completed. A third property, well-known in the field of fractals, is “self-similarity.”¹⁵ A fractal is self-similar when its structure appears the same at any scale.¹⁶ These properties are all characteristics of invention. Invention leads to a seemingly inexhaustible supply of technological solutions, even to comparatively simple problems.¹⁷ The potential of an inventive insight to produce such solutions does not reveal itself immediately; further investigation typically reveals more paths to explore. To some degree, inventive contributions are also self-similar. A refinement many steps removed from one path-breaking advancement may seem, in its own context, just as fundamental.

These properties underlie the difficulty of defining the invention to which a patentee is legally entitled. If inventions are, as a rule, only promontories on a larger continent, and themselves the source of elab-

⁸ See BENOIT B. MANDELBROT, *THE FRACTAL GEOMETRY OF NATURE* 42–43 (rev. ed. 1983) (illustrating and explaining how to create a Koch island).

⁹ See *id.* at 7–9 (discussing how fractals reveal infinite complexity as they are magnified).

¹⁰ See *id.*

¹¹ *Id.* at 1, 25.

¹² *Id.* at 25.

¹³ See *id.* at 26 (noting that the measured length of a coastline will be more accurate as smaller increments are used to measure it, but this measurement can never be entirely accurate).

¹⁴ MANDELBROT, *supra* note 8, at 26.

¹⁵ *Id.* at 34 (defining “self-similar” as “when each piece of a shape is geometrically similar to the whole”).

¹⁶ See *id.*

¹⁷ See *infra* notes 130–209 and accompanying text.

orations to come, to what territory is an inventor entitled to stake a claim? One can *define* a fractal promontory so as to distinguish it from the remainder of the figure, but one cannot *know* all that it contains, much less *describe* its contents to anyone else. This tension fuels some of the most stubborn problems in patent law.

Part I of this Article provides a basic primer on the subject of fractals, with particular emphasis on the Koch island and the much more elaborate Mandelbrot set.¹⁸ Part I also explains how researchers have discovered fractal properties in many real-world places, including in the branching inquiries of the common law.¹⁹ Part II discusses the fractal properties of invention, both as an individual endeavor and as a collective enterprise.²⁰ Part II also explains how one technological variation typically leads to further variations, generating a complex structure marked by the fractal properties of multiplicity, latency, and self-similarity.²¹ Part III explores the role of those fractal properties in several areas of patent law, including claim interpretation, the enablement and written description requirements, and the prohibition on patenting abstract ideas.²² Part III also argues that the ever-receding details of a fractal network create many of the analytical problems that beset those aspects of the patent system, including the difficulty of identifying “the invention.”²³

I. FRACTAL ODDITIES AND THEIR REAL-WORLD ANALOGS

“Fractal” is a term coined by Benoit Mandelbrot, the mathematician who pioneered the study of fractals half a century ago.²⁴ Mandelbrot’s 1983 book *The Fractal Geometry of Nature* collects some of his more accessible writings in the field. Fractals are easiest to explain by example, and one of the simplest fractals to envision is a Koch island, also known as a Koch snowflake.²⁵ Section I.A describes the Koch island.²⁶ Section

¹⁸ See *infra* notes 24–129 and accompanying text.

¹⁹ See *infra* notes 60–84 and accompanying text.

²⁰ See *infra* notes 130–212 and accompanying text.

²¹ See *infra* notes 130–212 and accompanying text.

²² See *infra* notes 213–461 and accompanying text.

²³ See *infra* notes 213–461 and accompanying text.

²⁴ JOHN BRIGGS, *FRACTALS: THE PATTERNS OF CHAOS: DISCOVERING A NEW AESTHETIC OF ART, SCIENCE, AND NATURE* 22 (1992). The term “fractal” apparently refers to the non-integer dimensions encountered in fractal geometry. See MANDELBROT, *supra* note 8, at 15. It may also suggest the “fractured” appearance of the “broken, wrinkled, and uneven shapes” that often appear. BRIGGS, *supra*, at 22.

²⁵ See MANDELBROT, *supra* note 8, at 42–43 (providing illustrations of Koch islands or snowflakes).

I.B describes a more complex fractal, the Mandelbrot set.²⁷ Section I.C provides examples of fractals that are found in nature and everyday life.²⁸ Section I.D explains some of the properties of fractals.²⁹ Section I.E shows how those fractal properties relate to the study of law.³⁰

A. *The Koch Island*

To construct a Koch island, begin with an equilateral triangle.³¹ Next, at the center of each side of that triangle, attach a smaller equilateral triangle, jutting outward from the center of the larger triangle.³² Make the length of each side of the smaller triangle one-third the length of the sides of the original triangle, so the figure now resembles a six-pointed Star of David.³³ Next, give each of these triangular points the same treatment.³⁴ In other words, at the middle of each exposed side, attach a still smaller outward-jutting triangle.³⁵ At this stage, the figure begins to resemble a snowflake, each point of the Star of David now multiplied to three.³⁶ Now continue the process indefinitely.³⁷ As each point or peninsula acquires its own smaller protuberances, the edge of the figure assumes ever more elaborate contours.³⁸ A true Koch island is the product of an infinite number of iterations.³⁹

A Koch island has curious properties. It is not, by any means, infinite in area.⁴⁰ If the Koch island illustrated in Mandelbrot's book were elaborated to an endless degree of complexity, it would still fit comfortably on the page.⁴¹ The length of the perimeter is another matter.⁴²

²⁶ See *infra* notes 31–50 and accompanying text.

²⁷ See *infra* notes 51–59 and accompanying text.

²⁸ See *infra* notes 60–84 and accompanying text.

²⁹ See *infra* notes 85–100 and accompanying text.

³⁰ See *infra* notes 101–129 and accompanying text.

³¹ MANDELBROT, *supra* note 8, at 42.

³² *Id.*

³³ *Id.*

³⁴ *Id.*

³⁵ *Id.*

³⁶ *Id.*

³⁷ MANDELBROT, *supra* note 8, at 42–43.

³⁸ See *id.* (illustrating the results of this process).

³⁹ See *id.* at 42 (instructing one who constructs a Koch island to continue this process “ad infinitum”).

⁴⁰ See *id.* at 42–43 (describing a Koch island as exhibiting “inner infinity,” as the additional augmentations are always squeezed into the form’s existing boundaries, which are limited by polygons connecting the points created in the previous stage).

⁴¹ See *id.*

⁴² See *id.* at 25–26 (explaining through the example of a coastline how the perimeter of a Koch island should be considered infinite).

A simple way to measure the perimeter of a figure is to take a straight measuring rod of length ϵ and march it around the edges, in the end multiplying ϵ by the number of times (L) the measuring rod fits.⁴³ Measuring a four-by-four square with a rod of length two by this method would be easy and precise. The rod would fit exactly eight times around the perimeter, and the result $L(\epsilon)$ would be sixteen. Measuring the perimeter of a circle by the same method is more difficult.⁴⁴ One could approximate by moving the straight rod around the edges of the circle perpendicular to a line from the center and counting the number of lengths before returning to where one began. But one would really be measuring the perimeter of a polygon in which the circle is inscribed, not the perimeter of the circle itself. One could improve the measurement by reducing the length of the measuring rod. The smaller rod would measure out a polygon of more sides, closer in length to the circle itself. No matter how small the measuring rod, the approximation would never be perfect. Nevertheless, as one employed smaller and smaller rods, the measurements would converge toward a definite figure equal to the diameter of the circle times π .⁴⁵

If that convergence takes place, the figure is "rectifiable."⁴⁶ With a Koch island, the convergence never happens.⁴⁷ A smaller measuring rod can follow more of the ins and outs at the edge of the figure, but it always misses those that are smaller still.⁴⁸ Each measurement by progressively smaller measuring rods simply produces a figure ($L(\epsilon)$) greater than the last.⁴⁹ A Koch island, though finite in area, has an *infinite* perimeter.⁵⁰

B. *The Mandelbrot Set*

The fractal most closely associated with Benoit Mandelbrot is the eponymous Mandelbrot set.⁵¹ The Mandelbrot set lies on a grid of in-

⁴³ MANDELBROT, *supra* note 8, at 25.

⁴⁴ *See id.* at 27.

⁴⁵ *See id.* (noting that such measurements of the perimeter of a circle would "increase but converge rapidly to a limit").

⁴⁶ *Id.*

⁴⁷ *Id.*

⁴⁸ *See id.* at 26 (explaining how ever more minute measurements are possible).

⁴⁹ MANDELBROT, *supra* note 8, at 26.

⁵⁰ *See supra* notes 40-45 and accompanying text.

⁵¹ *See* A.K. Dewdney, *Computer Recreations: A Computer Microscope Zooms in for a Look at the Most Complex Object in Mathematics*, *SCI. AM.*, Aug. 1985, at 16, 16 (discussing the Mandelbrot set).

finitesimal points representing complex numbers.⁵² To generate the Mandelbrot set, one subjects an array of numbers represented on that grid to an iterative process of calculation and recalculation.⁵³ If the result does not stray far from where it began, even after a number of iterations, the point on the grid representing the starting number is inside the Mandelbrot set.⁵⁴ If the result of the repeated calculation spins off to infinity, then the point where one began is outside of the Mandelbrot set.⁵⁵ One can “fill in,” on a computer’s display, the points on the grid that are within the Mandelbrot set.⁵⁶ The resulting shape looks something like a beetle with a rounded abdomen, a smaller head, and a series of protuberances and filigrees around the edges.⁵⁷

One can magnify a section of the edge by subjecting a portion of the original array to the same process as before, but on a finer scale—the starting points more closely packed and the figures carried to a higher number of decimal places.⁵⁸ The intricate landscape of curls and archipelagos generated by “zooming in” on the borders of the Mandelbrot set have a strange and alien beauty, and, unlike the Koch island, the details are not so regular as to be boring. In fact, any would-be explorer using widely available software can discover new details in the Mandelbrot set.⁵⁹ Its complexity is inexhaustible.

C. *Fractals Around Us*

Figures like the Koch island were known long before Mandelbrot, but mathematicians dismissed them as monstrosities outside of the natural order.⁶⁰ Mandelbrot showed that fractal properties are not freakish at all, but quite commonplace in nature.⁶¹ For example, Mandelbrot argued that the island of Britain exhibits the same difficulties of meas-

⁵² *Id.* Complex numbers are composed of two sets of numbers, one real and the other “imaginary.” *Id.*

⁵³ *See id.* (describing this iterative process).

⁵⁴ *Id.* at 17.

⁵⁵ *See id.*

⁵⁶ *See id.* at 17–19 (describing how a computer program can map the Mandelbrot set).

⁵⁷ *See* Dewdney, *supra* note 51, at 17 (providing an example of such a computer generated image).

⁵⁸ *See id.* at 17–19 (explaining how to create images of specific portions of the Mandelbrot set).

⁵⁹ *Mandelbrot Set Generator*, EASY FRACTAL GENERATOR, <http://www.easyfractalgenerator.com/Mandelbrot-Set-Generator.aspx> (last visited Jan. 16, 2012) (offering an on-line version of the software).

⁶⁰ *See* MANDELBROT, *supra* note 8, at 3 (referring to “pathological” figures and a “gallery of monsters”).

⁶¹ *Id.* at 3–4.

urement as a Koch island.⁶² Although a geographer could follow the coastline with a measuring rod, adding up the distances along each bay and peninsula, twists and turns smaller than the measuring rod—a stone here, a notch there—would have to be glossed over.⁶³ The geographer could follow smaller details with finer tools, “harnessing a mouse, then an ant, and so forth,” to the point of following the contours of each grain of sand on the beach with a microscope.⁶⁴ But each attempt would indicate a longer coastline, and, as with the Koch island, the measurements would never converge.⁶⁵ The length of a coastline, Mandelbrot wrote, is “an elusive notion that slips between the fingers of one who wants to grasp it.”⁶⁶ However it is measured, the length of any coast is essentially infinite.⁶⁷

Once Mandelbrot popularized the idea of fractals as natural occurrences, researchers observed fractal-like structures in a wide array of real-world phenomena, from the network of veins on a leaf⁶⁸ to the whorls of gas in interstellar space.⁶⁹ In the words of John Briggs, whose writings celebrate the aesthetic qualities of fractal geometry, “We see fractals every day. Trees, mountains, the scattering of autumn leaves in the backyard: all these are fractal patterns”⁷⁰ The intricacies of natural fractals are not truly inexhaustible, like the mathematical ideal, but, as Mandelbrot said of natural coastlines, their boundaries can be “[so] very large and so ill determined that [they are] best considered infinite.”⁷¹ Mandelbrot discovered fractal properties even in the fluctuations of the stock market.⁷²

Geometric fractals and their natural counterparts are the result of iterative processes, repeated and repeated ad infinitum.⁷³ In the natural context, Briggs refers to fractals as “the tracks and marks left by the pas-

⁶² See *id.* at 36 (“I claim that a Koch curve is a rough but vigorous model of a coastline.”).

⁶³ See *id.* at 26 (stating that a man “is too big and clumsy” to measure a coastline in increments of less than about fifty centimeters).

⁶⁴ *Id.*

⁶⁵ *Id.*

⁶⁶ See MANDELBROT, *supra* note 8, at 25.

⁶⁷ *Id.* “Hence, if one wishes to compare different coastlines from the viewpoint of their ‘extent,’ length is an inadequate concept.” *Id.*

⁶⁸ BRIGGS, *supra* note 24, at 37.

⁶⁹ *Id.* at 17.

⁷⁰ *Id.* at 22.

⁷¹ MANDELBROT, *supra* note 8, at 25.

⁷² BENOIT B. MANDELBROT & RICHARD L. HUDSON, *THE (MIS)BEHAVIOR OF MARKETS: A FRACTAL VIEW OF RISK, RUIN, AND REWARD* 6 (2004).

⁷³ See *infra* notes 74–78 and accompanying text.

sage of dynamical activity.”⁷⁴ In the case of a leaf, the “dynamical activity” encompasses the natural processes of growth;⁷⁵ in the case of a coastline, the natural processes of erosion.⁷⁶ A Koch island is a geometric construct defined by the method of its creation—a simple step applied and re-applied to the ever-evolving contour.⁷⁷ Mandelbrot used the term “cascade” to refer to the recursive process that generates a fractal.⁷⁸

The cascade may be “ascending,” beginning small and operating at ever-larger scales.⁷⁹ An example would be a process of joining minute dust particles into clumps, the clumps into larger clumps, and so on until the clumps are nothing less than galaxies.⁸⁰ A descending cascade is one that operates at ever smaller scales, like the mechanism for creating a Koch island.⁸¹ In either case, fractals are closely associated with processes or algorithms. The fractal-generating process can even be one of elimination.⁸² One can begin with a line, delete the middle third, delete the middle third of the two remaining segments, delete the middle third of the remaining four segments, and so on forever.⁸³ The result is a fractal set of points known as “Cantor dust,” after mathematician Georg Cantor.⁸⁴

D. *The Properties of Fractals*

Although fractals come in a wide variety of forms (Koch islands, natural coastlines, Cantor dust, the Mandelbrot set, and more), they share certain characteristics that are important to our discussion. The first of these I call “multiplicity.” The processes that create fractals subject their objects to geometric progressions of added complexity. After the first step, the figure that will evolve into a Koch island has three points; at the Star of David stage, six points; at the next stage, eighteen

⁷⁴ BRIGGS, *supra* note 24, at 22.

⁷⁵ *Id.* at 22.

⁷⁶ *Id.*

⁷⁷ See MANDELBROT, *supra* note 8, at 42–43 (supplying two methods for constructing a Koch island).

⁷⁸ See *id.* at 34 (describing the process of creating ever smaller details as a “cascade”).

⁷⁹ See *id.* at 93 (describing an “ascending cascade” as the accretion of small particles into a larger whole).

⁸⁰ *Id.*

⁸¹ See *id.* at 43, 93 (describing a Koch island as a descending cascade in which the space surrounding the figure is divided into smaller and smaller pieces).

⁸² BRIGGS, *supra* note 24, at 67.

⁸³ *Id.*

⁸⁴ *Id.*

points; then fifty-four points, etc.⁸⁵ The process that leads to Cantor dust begins with one line segment; then it is two line segments; then four, eight, sixteen, thirty-two, and so forth.⁸⁶ With true fractals, this progression leads on to infinity.⁸⁷ Natural fractal analogs, like the veins in a leaf, do not proceed to infinity, but, like the length of an actual coastline, after a point the multiplication may be treated as essentially limitless.⁸⁸ Briggs reproduces a verse of Jonathan Swift offering a whimsical take on nature's fractal scaling: "So, Nat'ralists observe, a Flea / Hath smaller Fleas that on him pray, / And these have smaller yet to bite'm, / And so proceed, *ad infinitum*."⁸⁹ Even if the progression of smaller fleas does *not* proceed *ad infinitum*, it would not take many generations before the numbers swelled to epic proportions.

A second, and related, fractal property I call "latency." A fractal is always, in a sense, a work in progress. The details of a Koch island emerge as one follows the steps of its construction. Because there are an infinite number of steps, a completed Koch island is something one can imagine but never produce. Perhaps the Mandelbrot set can be defined in advance by its mathematical properties,⁹⁰ but as far as human knowledge of its contents is concerned, that too is a matter of an ongoing process. The shapes that lie on the fringes of the Mandelbrot set will always include levels of detail as yet unobserved. The same is true of natural fractals of sufficient depth. If one could imagine freezing, for a moment, every process—from tectonic drift to Brownian motion—that alters the shores of Britain, perhaps the coastline would have a definite shape. But mapping that shape in all of its minute contours would be a process always shy of completion.

A third property of fractals is "self-similarity."⁹¹ Self-similarity means that similar patterns appear at any scale.⁹² Briggs illustrates self-similarity with a series of four photographs of a vine-covered wall, each

⁸⁵ See MANDELNBROT, *supra* note 8, at 42–43 (illustrating Koch islands at these stages).

⁸⁶ See BRIGGS, *supra* note 24, at 67 (illustrating the stages of this process).

⁸⁷ See *id.* at 66–67 (indicating that the processes used to create Cantor dust and Koch islands are repeated "indefinitely").

⁸⁸ See MANDELNBROT, *supra* note 8, at 26 (suggesting that even with ever smaller measuring tools, the contours of the coastline are always more minute, and the length increases without limit).

⁸⁹ Jonathan Swift, *On Poetry: A Rhapsody*, in BRIGGS, *supra* note 24, at 41.

⁹⁰ Certain properties of the Mandelbrot set have been mathematically proven, like the connection, if only by a narrow filament, of each portion of the set to the rest. See Dewdney, *supra* note 51, at 20 (referring to the theorem of Adrian Douady).

⁹¹ See MANDELNBROT, *supra* note 8, at 34 (describing "self-similarity" as "when each piece of a shape is geometrically similar to the whole").

⁹² See *id.*

magnifying a portion of the photograph that precedes it.⁹³ The photographs are not identical, yet they each exhibit a similar landscape of branching and interwoven tendrils.⁹⁴ The coastline of Britain is self-similar at a broad range of scales, so that one could not tell, by observing an outline, whether one was looking at the contours of many miles of coastline or only a few.⁹⁵ Geometric fractals have the same property of scale-independence.⁹⁶ Magnify a portion of a Koch island as much as you like, and you will always see the same pattern of triangles-upon-triangles that you saw before.⁹⁷ The Mandelbrot set is not as regular as that; the patterns one finds by magnifying portions of the Mandelbrot set are unpredictable.⁹⁸ Those patterns, however, are always broadly similar.⁹⁹ One of the intriguing properties of the Mandelbrot set is the reappearance at vast magnifications of beetle-like figures that closely resemble the Mandelbrot set as a whole—universes within universes.¹⁰⁰

E. Law as a Fractal

At least in the literature of patent law, the fractal properties of invention are seldom discussed. That does not mean that fractals are unknown in legal scholarship.¹⁰¹ In fact, *law itself* has been proposed as a fractal object.¹⁰² As we will see, the reasons for treating invention as a fractal object are much the same.

Professors advise law students facing their first round of fact-pattern-based exams to treat the issues presented as a tree of many branches. A successful analysis follows each branch to its conclusion, then backs up to follow, in the same fashion, alternative branches formed when a predicate question cannot be answered with certainty. In this respect at least, exams mirror reality. Legal analysis is a journey

⁹³ See BRIGGS, *supra* note 24, at 22–23 (providing and explaining a series of photographs of vines).

⁹⁴ *See id.*

⁹⁵ David G. Post & Michael B. Eisen, *How Long Is the Coastline of the Law? Thoughts on the Fractal Nature of Legal Systems*, 29 J. LEGAL STUD. 545, 551–52 (2000).

⁹⁶ *Id.* at 551.

⁹⁷ See BRIGGS, *supra* note 24, at 66 (illustrating Koch islands).

⁹⁸ See Dewdney, *supra* note 51, at 16, 19–20 (noting that, as one looks closely at portions of the Mandelbrot set, one sees shapes similar to the whole set, but not exactly the same).

⁹⁹ *See id.*

¹⁰⁰ *See id.*

¹⁰¹ See Post & Eisen, *supra* note 95, at 546 (proposing that legal arguments and case citations exhibit a fractal structure).

¹⁰² *See id.*

through a branching set of inquiries.¹⁰³ Although illustrations could be found in virtually any area of law,¹⁰⁴ copyright law serves as well as any.¹⁰⁵

The most basic question in a copyright suit is, who wins?¹⁰⁶ If plaintiff wins, the court proceeds to the available remedies for infringement; if defendant wins, the court dismisses the case. Plaintiff wins only if the court decides in its favor, at every turn, through a complicated series of inquiries.¹⁰⁷ Does the court have jurisdiction to decide the case?¹⁰⁸ If so, does plaintiff own the copyright to the work in question?¹⁰⁹ If so, is the copyright valid?¹¹⁰ If so, does defendant infringe?¹¹¹ Some of these questions lead to further, subsidiary questions.¹¹² With respect to validity, the court must inquire whether plaintiff's work is a work of authorship,¹¹³ whether it is original,¹¹⁴ and whether it is "fixed in a tangible medium of expression."¹¹⁵ On the infringement branch, the court must find proof of actionable copying.¹¹⁶ One option is direct proof—a wit-

¹⁰³ See J.M. Balkin, *The Crystalline Structure of Legal Thought*, 39 RUTGERS L. REV. 1, 4–13 (1986) [hereinafter Balkin, *Crystalline Structure*] (explaining how legal doctrines arose through a dialectic process of a series of dichotomous choices over time). Jack Balkin may have been the first to treat this branching structure as a fractal. He first referred to the "crystalline structure" of legal argument. *See id.* at 2–3. He determined later that "fractal structure" would have been a better term. J.M. Balkin, *The Promise of Legal Semiotics*, 69 TEX. L. REV. 1831, 1836 (1991). The same theme has been explored more recently by David Post and Michael Eisen. *See Post & Eisen, supra* note 95, at 546. They observe that "legal arguments have a kind of fractal structure—recursively generated and possessed of a branching, self-similar, tree-like structure at all levels of the argumentation hierarchy." *Id.*

¹⁰⁴ Balkin, *Crystalline Structure, supra* note 103, at 4–13.

¹⁰⁵ *See Post & Eisen, supra* note 95, at 554–55.

¹⁰⁶ *See id.* at 554 (noting that the central question in such a lawsuit is whether the defendant is liable to the plaintiff).

¹⁰⁷ *See id.* at 554–55 (describing the branching set of inquiries).

¹⁰⁸ *Id.* at 555.

¹⁰⁹ *See id.* at 554–55.

¹¹⁰ *See id.*

¹¹¹ Post & Eisen, *supra* note 95, at 554–55.

¹¹² *See id.*

¹¹³ *Id.* at 555; *see also* 17 U.S.C. § 102(a) (2006) ("Copyright protection subsists . . . in original works of authorship fixed in any tangible medium of expression . . ."); *Feist Publ'ns, Inc. v. Rural Tel. Serv. Co.*, 499 U.S. 340, 347 (1991) (stating that copyrightable works must "owe their origin to an act of authorship").

¹¹⁴ *See Post & Eisen, supra* note 95, at 555; *see also Feist*, 499 U.S. at 345 ("To qualify for copyright protection, a work must be original to the author.").

¹¹⁵ *See Post & Eisen, supra* note 95, at 555; *see also* 17 U.S.C. § 102(a) (requiring fixation in a tangible medium for copyright protection to attach); *Williams Elecs., Inc. v. Artic Int'l, Inc.*, 685 F.2d 870, 873–74 (3d Cir. 1982) (discussing the fixation requirement).

¹¹⁶ *See Ty, Inc. v. GMA Accessories, Inc.*, 132 F.3d 1167, 1169 (7th Cir. 1997) ("The Copyright Act forbids only copying; if independent creation results in an identical work, the creator of that work is still free to sell it.").

ness to the act. Without direct proof, plaintiff may establish copying through a combination of access to the copyrighted work plus “substantial similarity.”¹¹⁷ Determining whether the works are similar enough to be “substantially similar” requires “yet another two-part analysis.”¹¹⁸ First the court considers whether the works include extrinsically similar expression, applying objective criteria.¹¹⁹ If so, they must also be intrinsically similar, meaning that they present the same “total concept and feel” from the perspective of the intended audience.¹²⁰ In order to identify the intended audience, the court must determine if the work is meant for average adults, connoisseurs, or five-year-old children.¹²¹

Although the order of inquiry may differ—a court may jump straight to the issue of substantial similarity if the works are nothing alike—the structure itself is intrinsic to the law of copyright.¹²² Systems of law are organized into tree-like structures of question upon question, not unlike the promontory upon promontory that distinguishes a Koch island.¹²³ The branching here is a matter of categorization rather than geometry; the tree occupies a taxonomic space, rather than a physical space. And the branching does not go on forever, as it would with a true fractal; if it did, no court could ever reach a decision.¹²⁴ But the fractal metaphor is a useful one, as it is when discussing natural phenomena with similar properties.

The fractal nature of legal inquiry creates multiplicity. Copyright cases can be resolved in many different ways, depending on where the court’s journey through the doctrinal anfractuosités comes to rest.¹²⁵ Law also has the property of latency. Courts are ever in the process of elaborating upon the complex tangle of legal issues, driven in part by

¹¹⁷ See *Bouchat v. Balt. Ravens, Inc.*, 241 F.3d 350, 353–54 (4th Cir. 2000) (stating that such indirect evidence is sufficient when direct evidence of copying is unavailable).

¹¹⁸ *Lyons P’ship v. Morris Costumes, Inc.*, 243 F.3d 789, 801 (4th Cir. 2001).

¹¹⁹ See *Shaw v. Lindheim*, 919 F.2d 1353, 1356–57 (9th Cir. 1990) (describing the extrinsic test and its objective criteria). The analysis may differ in other circuits. See, e.g., *Lyons*, 243 F.3d at 801 (describing an extrinsic test for substantially similar “ideas”).

¹²⁰ *Lyons*, 243 F.3d at 801; see also *Shaw*, 919 F.2d at 1360 (describing the use of the “total concept and feel” standard).

¹²¹ See *Lyons*, 243 F.3d at 802.

¹²² See *Post & Eisen*, *supra* note 95, at 554–55 (noting that this inquiry can branch upwards through higher levels of abstraction and, depending on what the defendant contests, the court may not need to explore all of these branches).

¹²³ See *id.* at 550, 553 (comparing legal argumentation to a branching tree and a Koch island).

¹²⁴ See *id.* at 559 (“Each decided case represents a single instantiation of this process that has come to rest at some point, each opinion a single tree in the forest of judicial opinions.”).

¹²⁵ See *id.* at 554–55 (explaining the fractal structure of a copyright dispute).

new fact situations that had not presented themselves before.¹²⁶ Finally, legal inquiry is, in some respects, self-similar. Legal argument has “no ‘natural’ scale”: “We can always zoom in on any argumentative point, looking at it as the root of a deeply branching structure, or zoom out and look at it as a small part of a larger recursively branching structure.”¹²⁷ The branching process can only “in theory” continue forever.¹²⁸ It may not be true that we can “always” lose ourselves in the doctrinal thicket to the point that fundamental questions cannot be distinguished from minute refinements.¹²⁹ However, the branching exists at many levels and the *way* that the branching occurs seems indistinguishable. If one diagrammed, without labels, how one, multi-part legal inquiry leads to another, one could not tell whether a portion of that diagram represented a high-level or low-level analysis.

The idea that law is a fractal is important when we turn to technological rather than legal inquiries. The reason is that the fractal properties of law derive from the hierarchical, ever-branching nature of legal analysis; a general question leads to subsidiary questions, and so on through many levels. If the same is true of technological advancement, then invention, like law, has fractal characteristics.

II. THE FRACTAL PROPERTIES OF INVENTION

Invention is, in general, an effort to discover new technological solutions to the needs of mankind.¹³⁰ As observed by Henry Petroski, an engineer and historian who has studied the origins of technological artifacts as familiar as pencils and toothpicks,¹³¹ “Unlike problems in

¹²⁶ See, e.g., *Sid & Marty Krofft Television Prods., Inc. v. McDonald's Corp.*, 562 F.2d 1157, 1164–65 (9th Cir. 1977) (engaging for the first time in the intrinsic/ extrinsic analysis of “substantial similarity”), *superseded on other grounds by statute*, Copyright Act of 1976, Pub. L. 94-553, 90 Stat. 2541 (1976). In 1990, the U.S. Court of Appeals for the Ninth Circuit revised and embellished the analysis further. See *Shaw*, 919 F.2d at 1356–57 (explaining how cases since *Krofft* have further developed the standard and characterizing the analysis as objective/subjective, instead of extrinsic/intrinsic). Future cases will no doubt continue the work.

¹²⁷ Post & Eisen, *supra* note 95, at 558.

¹²⁸ See *id.* at 558 & n.25 (explaining that it may always be possible to continue to subdivide legal issues into new branches).

¹²⁹ See *id.* at 558 (suggesting that, as one zooms in and out through legal argumentation, all portions have a similar branching structure).

¹³⁰ STEVEN J. PALEY, *THE ART OF INVENTION: THE CREATIVE PROCESS OF DISCOVERY AND DESIGN* 23 (2010) (explaining that most inventions were developed to solve a preexisting problem).

¹³¹ See generally HENRY PETROSKI, *THE PENCIL: A HISTORY OF DESIGN AND CIRCUMSTANCE* (paperback ed. 1992) (discussing the origins of the pencil); HENRY PETROSKI, *THE TOOTHPICK: TECHNOLOGY AND CULTURE* (2007) (describing the history of the toothpick).

mathematics, which practically always have a unique answer, a single problem in engineering and technology can have many different solutions.¹³² Those solutions are not isolated; they are, instead, *connected* through a network of questions and answers—a network limited only by the imagination of inventors and the laws of natural science. Invention is a journey through diverging paths that lead in many directions; each destination, in turn, suggests new paths to follow. Like legal analysis, invention can be compared to the continuous branching of the Koch island.

Section II.A describes inventions that are created by individuals,¹³³ whereas Section II.B describes inventions that are the products of collaborative processes, such as expanding and improving prior inventions.¹³⁴ Section II.C examines the fractal properties of multiplicity, latency, and self-similarity in those processes of invention.¹³⁵ Section II.D discusses the difficulties associated with modeling these processes of invention as geometric fractals.¹³⁶

A. *Invention by Individuals*

Much of what we know about invention is anecdotal. In the popular imagination, the “flash of genius,” in which the inventor/hero, in a burst of inspiration, beholds the invention entire in his imagination, still plays a prominent role.¹³⁷ But even when such sudden insights can be documented, they are likely accompanied by a step-by-step process of implementation and improvement. The invention of hook-and-loop fasteners (generally known as Velcro) supplies a good example.¹³⁸ In 1848, when Swiss inventor George de Mestral returned from an amble in the woods with his dog, he discovered cockleburs stuck to his clothing.¹³⁹ His “flash of genius” was to imagine a clothing fastener based on

¹³² HENRY PETROSKI, *INVENTION BY DESIGN: HOW ENGINEERS GET FROM THOUGHT TO THING* 112 (1996).

¹³³ See *infra* notes 137–155 and accompanying text.

¹³⁴ See *infra* notes 156–191 and accompanying text.

¹³⁵ See *infra* notes 192–209 and accompanying text.

¹³⁶ See *infra* notes 210–212 and accompanying text.

¹³⁷ A recent motion picture about an inventor and his struggles used “Flash of Genius” as its title. *FLASH OF GENIUS* (Universal Pictures 2008). The term dates back to the Supreme Court’s decision in *Cuno Engineering Corp. v. Automatic Devices Corp.*, 314 U.S. 84, 91 (1941). By adopting the nonobviousness standard in the 1952 Patent Act, Congress disavowed the notion that patentability must reflect “genius.” *Graham v. John Deere Co.*, 383 U.S. 1, 15 (1966).

¹³⁸ See PETROSKI, *supra* note 132, at 78–80 (recounting the story of the invention of Velcro).

¹³⁹ *Id.* at 78.

the same physical mechanism, shown by microscopic examination to be tiny hooks in the cockleburs entangled in the threads of his clothing.¹⁴⁰ “Almost immediately,” de Mestral envisioned complementary pieces of fabric, one lined with hooks and the other with loops, that could be combined as a “soft but tenacious fastener” for clothing.¹⁴¹

This immediate insight did not produce a viable product until six years later.¹⁴² In spite of the soundness of the general idea, “many questions . . . had to be faced,” such as “how many hooks [the fastener] should have, of what material they should be made, how they should be formed, and so forth.”¹⁴³ Answering these questions required exploring a number of alternatives.¹⁴⁴ The optimal number of loops proved to be 300 per square inch, and nylon was identified as a superior material to the cotton used in the prototype.¹⁴⁵ Further discoveries emerged in the development process, including the use of infrared light to toughen the nylon.¹⁴⁶

Even this simple story of invention exhibits fractal characteristics. Of all the ways one might fasten clothing, de Mestral pursued the path of miniature hooks and loops. From that beginning stemmed alternative paths of cotton and nylon, and from the choice of nylon alternative paths of treated or untreated material. The well-known story of Edison’s search for a practical light bulb filament suggests similar branching.¹⁴⁷ Edison’s team tested both metals, like platinum, and carbonized natural fibers, like slivers of wood.¹⁴⁸ Among the varieties of wood tested were hickory, rosewood, and spruce.¹⁴⁹ The experimenters tried the same materials in a variety of shapes: “boxes, spirals, circles, horseshoes, and fanciful sprouts and curlicues.”¹⁵⁰ The first success came with a horseshoe-shaped carbonized cotton thread.¹⁵¹

¹⁴⁰ See *id.* at 79 (stating that de Mestral devised his invention upon observing cockleburs under a microscope).

¹⁴¹ *Id.*

¹⁴² *Id.* at 80.

¹⁴³ *Id.* at 79–80.

¹⁴⁴ See PETROSKI, *supra* note 132, at 80 (explaining how the invention was developed and refined).

¹⁴⁵ *Id.*

¹⁴⁶ *Id.*

¹⁴⁷ See JANE BROX, *BRILLIANT: THE EVOLUTION OF ARTIFICIAL LIGHT* 115–16 (2010) (describing the process of trial-and-error by which Edison discovered the best filament).

¹⁴⁸ *Id.* at 115.

¹⁴⁹ *Id.*

¹⁵⁰ *Id.*

¹⁵¹ *Id.* at 116.

The thought process of the inventor may or may not follow an orderly path. Some inventors adopt a “systems approach” or “top-down” method of problem solving that looks at the major systems or functional elements of the invention before focusing on the smaller details.¹⁵² Software engineering typically proceeds in this way.¹⁵³ The designer “charts out the major functional areas in very general terms and then logically connects them—all before writing a single line of programming code.”¹⁵⁴ In contrast, the inventor of the implantable pacemaker preferred a “big jump” to prove the value of a concept, followed by backtracking to “fill in the gaps.”¹⁵⁵ Regardless of which procedure an inventor chooses, the underlying structure is the same. An inventor begins with a problem to be solved and a number of paths to pursue. From each of those paths branch further paths, in an ever-expanding network of possibilities. For each question in the form, “How can that be done?,” there is more than one answer. And, for each answer another question: “How, in turn, can *that* be done?”

B. *Invention as a Collective Endeavor*

The fractal nature of invention is more apparent if one looks at invention as a collective enterprise. George Basalla regards technological development, as a whole, as a grand evolutionary process.¹⁵⁶ “[O]nce we actively search for continuity,” he writes, “it becomes apparent that every novel artifact has an antecedent. . . . Whenever we encounter an artifact, no matter what its age or provenance, we can be certain that it was modeled on one or more preexisting artifacts.”¹⁵⁷ Even breakthrough inventions like Eli Whitney’s cotton gin were modi-

¹⁵² PALEY, *supra* note 130, at 158.

¹⁵³ *Id.*

¹⁵⁴ *Id.*; see also *Computer Assocs. Int’l, Inc. v. Altai, Inc.*, 982 F.2d 693, 697–98 (2d Cir. 1992) (describing the top-down process of computer program design, beginning with the identification of the program’s “ultimate function or purpose,” and ending with the program code).

¹⁵⁵ See KENNETH A. BROWN, *INVENTORS AT WORK: INTERVIEWS WITH 16 NOTABLE AMERICAN INVENTORS* 29 (1988).

In the pacemaker, for example, throwing a bunch of parts together and touching the wires to a dog’s heart to make it beat—that was a big jump. After that jump, I could go back and fill in different details: What kind of materials can be used in the body? What kind of circuitry can be used?

Id.

¹⁵⁶ See BASALLA, *supra* note 6, at 208–09 (explaining the diversity of human artifacts through a theory of continuous technological evolution).

¹⁵⁷ *Id.*

fications of existing technology.¹⁵⁸ In Basalla's view, *everything* connects.¹⁵⁹ An "omniscient intelligence . . . capable of knowing the antecedents of all existing and vanished artifacts" would have the ability to "reconstruct the grand and vast network of linked artifacts that constitute the history of material culture."¹⁶⁰ This network would converge and all streams unite at "that remote point in time when the first object was shaped by protohuman hands."¹⁶¹

One need not be omniscient to observe the connectedness of inventive ideas. As Petroski has shown, even as humble an artifact as the paper clip is the product of a complex web of technological development.¹⁶² Paper clips rely on the natural properties of elasticity discovered by physicist Robert Hooke.¹⁶³ Since the development of steel wire in the latter part of the nineteenth century, paper clips have been devised in a staggering variety of shapes.¹⁶⁴ They come in the form of rectangles, triangles, circles, ovals, and tortuous figures that have no name.¹⁶⁵ Each variation "evolved in response to the failure of existing forms to reach perfection."¹⁶⁶ And each clip became, in turn, "an object of criticism"—an inspiration for inventors who, "perhaps just by giving this or that leg of a paper clip a slightly different bend, turn, or twist," thought to eliminate the shortcomings of the existing design.¹⁶⁷

The paper clip we commonly see today is known as the Gem clip.¹⁶⁸ Its elongated, round-ended, loop-within-a-loop shape is so famil-

¹⁵⁸ *Id.* at 33–34.

¹⁵⁹ *See id.* at 209 (stating that every artifact from every age was modeled on something that came before).

¹⁶⁰ *Id.*

¹⁶¹ *Id.*

¹⁶² *See* PETROSKI, *supra* note 132, at 10–27 (describing the evolution of the paper clip).

¹⁶³ *See id.* at 11 (describing how the principle of elasticity has contributed to the art of paper fastening). "What Hooke discovered was that, up to a limit, each object stretches in proportion to the force applied to it. Conversely, the more we stretch something elastic, the more resistance it offers to being further stretched." *Id.*

¹⁶⁴ *See* HENRY PETROSKI, *THE EVOLUTION OF USEFUL THINGS* 59, 62 (1992).

¹⁶⁵ *See id.* at 60–77 (illustrating several paper clip designs).

When all is said and done, any attempt to sort out the origins and the patent history of the paper clip may be an exercise in futility. For there appear to have been countless variations on the device, a great multiplicity of forms, and some of the earliest and most interesting versions seem not to have been patented at all . . .

Id. at 62.

¹⁶⁶ *Id.*

¹⁶⁷ PETROSKI, *supra* note 132, at 16.

¹⁶⁸ *Id.*

iar that, for many of us, the Gem is what we mean by “paper clip.”¹⁶⁹ The ubiquity of the Gem clip attests to the strengths of its design. Gem clips are inexpensive, simple, intuitive, and effective.¹⁷⁰ But they are not perfect. Their grip can be tenuous, particularly if metal fatigue sets in.¹⁷¹ Their exposed wire ends can snag pages.¹⁷² And they frequently become entangled in the box, or when sets of clipped pages are kept together.¹⁷³ The Gem clip has long been the starting point for improved designs meant to address these shortcomings.¹⁷⁴ The chief rival of the Gem clip is the Gothic clip, so named because its pointed ends resemble Gothic arches, in contrast to the Romanesque contours of the Gem.¹⁷⁵ The Gothic clip, patented by Henry Lankenau in 1934, has longer “legs” than a Gem clip.¹⁷⁶ This reduces the snagging potential and, because it is less likely to damage the paper, the Gothic clip can be made of heavier wire for a stronger grip.¹⁷⁷ These advantages have made the Gothic clip a favorite among librarians.¹⁷⁸ Yet even the Gothic clip is not, necessarily, the apotheosis of the paper clip. The first page of Lankenau’s patent shows not one clip design but several.¹⁷⁹ Some have points on the inner and outer loops, some have squared ends on the outer loop, some have indentations (curved or pointed) on either loop, and some feature rakish angles that are difficult to describe.¹⁸⁰

If one were to diagram the full spectrum of paper clip designs, all relying on steel wire and the fundamental properties of elasticity, the elongated double-loop racetrack configuration—exemplified by the Gem clip—would occupy only a small corner of the diagram. A small corner of *that* corner might be devoted to the long-legged Gothic designs, with further subdivisions devoted to each of Lankenau’s alternatives. Each variation is the starting point for further variations—a pro-

¹⁶⁹ See PETROSKI, *supra* note 164, at 68 (“Indeed, to the vast majority of people today it is virtually synonymous with paper clip.”).

¹⁷⁰ See *id.* at 70 (“The common paper clip is light, inexpensive, strong, easy to use, and quite good-looking.” (quoting PAUL GOLDBERGER, *ON THE RISE: ARCHITECTURE AND DESIGN IN A POSTMODERN AGE* 288 (1985))).

¹⁷¹ See *id.* at 73 (discussing improvements on the Gem clip to give it more gripping power).

¹⁷² See *id.* at 71–72 (discussing improvements to the Gem clip to prevent snagging).

¹⁷³ See PETROSKI, *supra* note 132, at 25–26 (discussing this disadvantage of the Gem design).

¹⁷⁴ *Id.* at 19.

¹⁷⁵ *Id.*

¹⁷⁶ *Id.*

¹⁷⁷ *Id.*

¹⁷⁸ *Id.*

¹⁷⁹ U.S. Patent No. 1,985,866 figs.1–9 (filed Nov. 23, 1933) [hereinafter ‘866 Patent].

¹⁸⁰ *Id.*

gression suggesting a fractal network. Of course, not every path leads to a successful product. Most paper clip variations are known only to those who have studied their development as a matter of historical interest. So far, most of the branches in the paper clip family tree lead to dead ends.¹⁸¹ As George Basalla, who finds continuity in all technological development, writes:

[A]ll variants of an artifact are not of equal importance. Some are simply inoperable; some are ineffective; and some are effective but have little technological and social influence. Only a few variants have the potential to start a new branching series that will greatly enrich the stream of made things, have an impact on human life, and become known as “great inventions” or “turning points in the history of technology.”¹⁸²

Although many developments lead nowhere, Basalla’s reference to “a new branching series” is a telling one.

Basalla contends that the basic continuity of technological development has been “obscured by the myth of the heroic inventor genius, by nationalistic pride, by the patent system, and by the tendency to equate technological change with social, scientific, and economic revolutions.”¹⁸³ As far as the patent system is concerned, his observation must be qualified. By singling out certain technological advancements as patentable inventions, and by excluding achievements within the reach of the “person of ordinary skill in the art,” the patent system emphasizes *discontinuity*.¹⁸⁴ Nevertheless, artifacts of the connectedness of invention appear everywhere in patent law.

Section 101 of the Patent Act promises exclusive rights to the discoverer of a “process, machine, manufacture, or composition of matter, or any new and useful *improvement thereof*.”¹⁸⁵ One who discovers a non-obvious species of a patented genus can obtain a patent on the species, leading to “blocking patents” that prevent either party from exploiting

¹⁸¹ See PETROSKI, *supra* note 132, at 16 (noting that few of the early designs for paper clips have survived the test of time).

¹⁸² BASALLA, *supra* note 6, at 34.

¹⁸³ *Id.* at 208.

¹⁸⁴ See 35 U.S.C. § 103(a) (2006), *amended by* Leahy-Smith America Invents Act, Pub. L. No. 112-29, § 3(c), (n), 125 Stat. 284, 287, 293 (2011) (effective Mar. 16, 2013) (stating that an invention may not be patented if “the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art”).

¹⁸⁵ 35 U.S.C. § 101 (emphasis added).

the narrower invention.¹⁸⁶ Most patents feature dependent claims, covering more specific variants of the invention than those encompassed by the independent claims.¹⁸⁷ And whether the alternative embodiments are separately claimed or not, many patents, like Lankenau's Gothic clip patent, disclose different ways in which the invention may be practiced.¹⁸⁸ All of these things indicate a succession of variations within variations, a theme echoed in the thematic classes and subclasses used by the Patent and Trademark Office to categorize inventions as potential prior art.¹⁸⁹ In the field of mousetraps, for example, class 43 covers Fishing, Trapping, and Vermin Destroying. Traps begin with subclass 58, and include categories for traps that imprison, electrocute, choke, squeeze, smite, impale, and blow up their victims.¹⁹⁰ Some of these are broken down further. Subclass 94, for example, covers the "wedge or toggle" option for the subclass 93 "direct engagement" version of the subclass 92 "modified trigger mechanism" variant of the basic subclass 88 "jaw" trap.¹⁹¹

In spite of the mythic attraction of the "heroic inventor genius," it should be an uncontroversial proposition that technological progress is, in general, a process of evolution, variation, and improvement. Most inventions, at least, are a part of a larger network of inventions. If that network is a fractal network in which one advancement leads to another and another, one would expect to find, in the realm of invention, the fractal properties of multiplicity, latency, and self-similarity.

¹⁸⁶ See *Prima Tek II, L.L.C. v. A-Roo Co.*, 222 F.3d 1372, 1379 n.2 (Fed. Cir. 2000) ("A 'blocking patent' is an earlier patent that must be licensed in order to practice a later patent. This often occurs, for instance, between a pioneer patent and an improvement patent."); *Utter v. Hiraga*, 845 F.2d 993, 998 (Fed. Cir. 1988) ("There is no inconsistency in awarding a generic count to one inventor, while awarding a patentably distinct species count to another . . ."); Kevin Emerson Collins, *The Reach of Literal Claim Scope into After-Arising Technology: On Thing Construction and the Meaning of Meaning*, 41 CONN. L. REV. 493, 510–12 (2008) (describing features of blocking patents through examples).

¹⁸⁷ See *Monsanto Co. v. Syngenta Seeds, Inc.*, 503 F.3d 1352, 1357 (Fed. Cir. 2007).

¹⁸⁸ See, e.g., '866 Patent, *supra* note 179, figs.1–9 (showing several ways to make the Gothic clip).

¹⁸⁹ See *US Classes by Number Menu*, U.S. PATENT & TRADEMARK OFFICE (Aug. 11, 2011, 5:43 PM), <http://www.uspto.gov/web/patents/classification/selectbynum.htm> (providing links to all such classes by their index numbers).

¹⁹⁰ *Class 43, Fishing, Trapping, and Vermin-Destroying*, U.S. PATENT & TRADEMARK OFFICE (Aug. 11, 2011, 5:43 PM), <http://www.uspto.gov/web/patents/classification/uspc043/sched043.htm>.

¹⁹¹ *Id.*

C. *Multiplicity, Latency, and Self-Similarity*

As the paper clip example suggests, technological artifacts come in an astonishing variety of forms.¹⁹² An illustration reproduced by Basalla depicts fifty-seven designs for smokestack spark arrestors—a sampling of the more than one thousand such designs patented in the nineteenth century, when embers from wood-burning locomotives were a frequent source of brushfires.¹⁹³ Petroski reviews the enormous diversity to be found in the design of hammers and nails,¹⁹⁴ and he reports that nineteenth century foresters could choose from an impressive array of axe designs—including Georgia, Jersey, Kentucky, North Carolina, Maine, or Michigan axes—depending on their needs and geographic loyalties.¹⁹⁵ Of all the varieties of technology devised by humanity, only a very small fraction is likely to be patented.¹⁹⁶ Yet if one counts as separate “species” just the inventions patented in the United States (a figure above eight million,¹⁹⁷ not counting the variations that might be separately claimed in a single patent), the level of diversity in the technological realm begins to rival that of biological diversity.¹⁹⁸

Technology evolves in such a variety of forms because of the many choices facing the inventor. One fork in the road leads to the next. Even if each branching represents only two, or three, or a dozen alternatives, the geometric progression soon multiplies the possibilities enormously, just as the intricacies of a Koch island exceed the resolving powers of the human eye after only a few generations. The choices pursued depend on the imagination of the inventor and the tradeoffs that the inventor is willing to accept—perhaps for the sake of serving a specialized set of needs. Hence, the world has seen hammers, axes, and spark arrestors designed in countless forms. And there is no sign of slowing down. In 2010, the Patent Office issued more than 219,000 pa-

¹⁹² See BASALLA, *supra* note 6, at 1 (referring to the easily overlooked “diversity of things made by human hands”).

¹⁹³ *Id.* at 136.

¹⁹⁴ PETROSKI, *supra* note 164, at 128–29.

¹⁹⁵ *Id.* at 126.

¹⁹⁶ See *id.* at 62 (noting that many early forms of the paper clip were never patented).

¹⁹⁷ See Press Release, U.S. Patent & Trademark Office, United States Patent and Trademark Office Issues Patent Number 8,000,000 (Aug. 16, 2011), available at <http://www.uspto.gov/news/pr/2011/11-47.jsp>; U.S. Patent Activity: Calendar Years 1790 to the Present, U.S. PATENT & TRADEMARK OFFICE (Apr. 1, 2011, 10:20 AM), http://www.uspto.gov/web/offices/ac/ido/oeip/taf/h_counts.htm [hereinafter *Patent Activity*] (supplying a year-by-year count of patents and patent applications since 1790).

¹⁹⁸ See BASALLA, *supra* note 6, at 2 (“[T]his attempt at measuring comparative diversification suggests that the diversity of the technological realm approaches that of the organic realm.”).

tents—a new record.¹⁹⁹ Like the twists and turns of the coast of Britain, the shores of invention appear to be, for practical purposes, limitless.

Invention also exhibits the property of latency. Like the endlessly multiplied details of a fractal curve, invention is always a work in progress. The “cascade” that extends the borders of invention is the process of inquiry and the pursuit of new alternatives. Invention is an “*iterative process*,” wherein “[w]e take a step, look around, assess, and then go on to the next step.”²⁰⁰ The tensions between plan and implementation compel changes in both, at first “large and sweeping,” but after “successive iterations” increasingly “smaller and more refined.”²⁰¹ The process is “asymptotic,” meaning that the adjustments become smaller as they produce diminishing returns, but it is never complete.²⁰²

The most debatable point is whether the continuous branchings of invention exhibit self-similarity; in other words, whether the pattern is basically the same when we are dealing with the kind of breakthroughs that, in Basalla’s words, “will greatly enrich the stream of made things, have an impact on human life, and become known as ‘great inventions,’”²⁰³ or only the more mundane refinements that go on every day. No one would deny that some inventions are more fundamental than others. The Wright brothers’ patent on the flying machine is nearer the trunk of the tree than the latest refinement in airfoil design. But self-similarity does not require that all inventions be the same, any more than it requires that each triangle added to the Koch island be of the same size, or that the patterns of the Mandelbrot set repeat themselves exactly. The issue is whether the branching that occurs at one level is different in some respect than the branching that occurs at another. Are there, for example, fewer choices as one goes on? Does the geometric progression expand at the same rate always, or does it begin to contract?

The remark that invention is “asymptotic” might suggest contraction.²⁰⁴ If there were perfect technological solutions to human problems, then one would expect the process of design to hone in on those few by ever finer measures, just as one comes closer and closer to the true diameter of a circle by employing ever smaller measuring rods.

¹⁹⁹ See *Patent Activity*, *supra* note 197 (listing the numbers of patents granted each year).

²⁰⁰ PALEY, *supra* note 130, at 171.

²⁰¹ *Id.* at 166.

²⁰² *Id.* at 167.

²⁰³ BASALLA, *supra* note 6, at 34.

²⁰⁴ See PALEY, *supra* note 130, at 167 (stating that, at a certain point, further changes will result in “diminishing returns”).

Technological solutions would be, in the language of fractal geometry, "rectifiable."²⁰⁵ Some classic designs, like the Gem paper clip, seem to occupy regions of stability. The Gem performs its function so well that attempts to introduce improvements may have encountered diminishing returns. On the other hand, Petroski insists that "[s]ince nothing is perfect, and, indeed, even our ideas of perfection are not static, everything is subject to change over time. There can be no such thing as a 'perfected' artifact; the future perfect can only be a tense, not a thing."²⁰⁶ Perhaps some new critic of the Gem design will discover the alternative that launches a paper-fastening revolution.²⁰⁷

No one can say for certain whether technological development will always go on as it has, nor does it matter for our purposes. As the volume of activity at the Patent Office suggests, the pace of innovation has not slowed,²⁰⁸ and today's inventions seem as likely as those of the past to supply the basis for further improvements, or, in Basalla's words, "new branching series."²⁰⁹

D. *The Shape of Invention*

Although the ever-multiplying promontories of the Koch island are a convenient metaphor for the ever-expanding frontiers of invention, in some respects, that simplest of fractals is too simple to capture the complexities of technological advancement. For one thing, it does not account for the finished designs that are put to use. In theory, one might explore the possibilities of hook-and-loop fasteners forever; in practice, firms that produce Velcro answer, at least provisionally, every question that might be asked about how the product should be made. The "coastline" of Velcro, like the perimeter of a Koch island, may be infinite. In other words, one may never exhaust all of the possibilities for how hook-and-loop fasteners could be devised. Nevertheless, there are established *points* on that coastline representing completed designs. Or, to change analogies, there are fruits hanging from the boughs of

²⁰⁵ See MANDELBROT, *supra* note 8, at 27 (describing a curve as "rectifiable" when approximate measurements of its length converge rapidly to a limit, as measurements of a circle's circumference converge to π times the diameter of the circle).

²⁰⁶ PETROSKI, *supra* note 164, at 22.

²⁰⁷ See PETROSKI, *supra* note 132, at 42 ("It is unlikely that there will be an end to new ideas for paper clips any time soon . . .").

²⁰⁸ See *Patent Activity*, *supra* note 197 (listing the numbers of patents granted each year).

²⁰⁹ See BASALLA, *supra* note 6, at 34 (explaining that, although some innovations lead to dead ends, others will give rise to a "new branching series").

invention, and they are not forever out of reach due to the endless branching of the tree. The fruits can be, and some have been, picked.

The Koch island is also too orderly a fractal to embody the genuine messiness of technological advancement. Basalla provides an illustration contrasting the tree of organic life to the tree of technological artifacts.²¹⁰ The former looks like a conventional tree, with branches dividing and dividing again, until the limbs are reduced to a multitude of twigs.²¹¹ The tree of artifacts, on the other hand, is a tangle of interconnections, reflecting the potential of one avenue of technological development to contribute to another.²¹² Advances in metallurgy, for example, might connect with advances in airfoils, mousetraps, *and* paper clips.

Furthermore, any attempt to diagram the island of technology would have an arbitrary character in comparison to the inevitable growth of a Koch island. If we return to the simple example of Velcro, one's diagram might feature hook-and-loop fasteners as the "main branch," followed by subbranches for the alternatives of cotton and nylon, with nylon further subdivided into infrared-treated and untreated fabric. On the other hand, one could just as easily begin with nylon fasteners as the "main branch," followed by subbranches for nylon zippers and nylon hook-and-loop fasteners. The actual paths of technological development are matters of historical accident. If one could diagram technological relationships in a more abstract, timeless fashion, something more complicated than a Koch island would be required.

In spite of these complexities, the basic point remains—technological progress is an ongoing, interconnected, continuously branching endeavor that exhibits some of the characteristics of a fractal. The problems this creates for a legal system devoted to assigning individuals exclusive rights to inventions are discussed in the Part III.

III. FRACTALS AND THE PATENT SYSTEM

The primary justification for awarding patents in the United States is set forth in Article I, Section 8 of the U.S. Constitution.²¹³ Patents "promote the Progress of the useful Arts," by allowing inventors, for a

²¹⁰ *Id.* at 138.

²¹¹ *Id.*

²¹² *Id.*

²¹³ U.S. CONST. art I, § 8, cl. 8 (granting Congress the power "To promote the Progress of Science and the useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries").

limited time, exclusive rights to income made from their inventions.²¹⁴ During the term of the patent, the owner has the exclusive right to make, use, sell, offer to sell, or import into the United States the invention set forth in the claims.²¹⁵

Originally, the patent system relied on “central claiming” to identify the invention that was the subject of exclusive rights.²¹⁶ In a system of central claiming, the patentee provides examples of the invention through detailed descriptions.²¹⁷ Today’s system of “peripheral claiming” relies on separate patent claims—carefully worded sentences that appear at the end of the patent document—to describe the “metes and bounds” of the patentee’s rights.²¹⁸ The claims enumerate a combination of elements that constitute the patented invention.²¹⁹ If an accused product includes all the elements of a claim, as properly construed, that claim is infringed.²²⁰ The claims must “particularly point[] out and distinctly claim[] the subject matter which the applicant regards as his invention.”²²¹ A claim that cannot be understood by persons skilled in the art may be rejected, or invalidated, on grounds of indefiniteness.²²²

In the remainder of the patent, known as the “specification,” the applicant provides drawings and prose descriptions to satisfy the disclosure requirements of the first paragraph of section 112 of the Patent Act.²²³ Section 112 demands a “written description of the invention, and of the manner and process of making and using it, in such full,

²¹⁴ See *Kewanee Oil Co. v. Bicron Corp.*, 416 U.S. 470, 480 (1974) (describing how the patent laws accomplish this constitutional objective by granting exclusive rights to the inventor to recoup the costs of research and development).

²¹⁵ 35 U.S.C. § 271(a) (2006).

²¹⁶ Dan L. Burk & Mark A. Lemley, *Fence Posts or Sign Posts? Rethinking Patent Claim Construction*, 157 U. PA. L. REV. 1743, 1746 (2009).

²¹⁷ See Jeanne C. Fromer, *Claiming Intellectual Property*, 76 U. CHI. L. REV. 719, 726–27 (2009) (explaining that, under a central claiming system, infringement is shown by comparing the accused product to several specific examples disclosed in the patent); Collins, *supra* note 186, at 502 (explaining that a central claim consists of disclosing a prototype to which alleged infringing products are compared).

²¹⁸ See *In re Warmerdam*, 33 F.3d 1354, 1360 (Fed. Cir. 1994) (“It is the claims which define the metes and bounds of the invention entitled to the protection of the patent system.”).

²¹⁹ See Collins, *supra* note 186, at 501 (explaining that claims “specify the necessary and sufficient criteria for the inclusion of a thing within the set of things” over which the patentee has exclusive rights).

²²⁰ *Techsearch, L.L.C. v. Intel Corp.*, 286 F.3d 1360, 1371 (Fed. Cir. 2002).

²²¹ 35 U.S.C. § 112, para. 2 (2006), *amended by Leahy-Smith America Invents Act*, Pub. L. No. 112-29, § 4(c), (e), 125 Stat. 284, 296–97 (2011) (effective Sept. 16, 2012).

²²² *Microprocessor Enhancement Corp. v. Tex. Instruments Inc.*, 520 F.3d 1367, 1374 (Fed. Cir. 2008).

²²³ See 35 U.S.C. § 112, para. 1 (requiring the specification to contain a written description of the invention).

clear, concise, and exact terms as to enable any person skilled in the art . . . to make and use the same.”²²⁴ Section 112 also requires the inventor to disclose “the best mode contemplated by the inventor of carrying out his invention.”²²⁵ The enablement and best mode requirements are a part of the patentee’s “bargain.”²²⁶ In exchange for exclusive rights, the patentee must teach those skilled in the art how to practice the claimed invention without “undue experimentation.”²²⁷ The specification also plays an important role in interpreting claim language.²²⁸

A patentable invention must be “useful,”²²⁹ and it must fall within one of the statutory categories of “process, machine, manufacture, or composition of matter.”²³⁰ “Abstract ideas” cannot be patented.²³¹ The invention must be new in comparison to the prior art,²³² and it must not have been obvious, when it was made, “to a person having ordinary skill in the art.”²³³

To see how these rules of patent law accommodate an actual invention, I will use as an example the apparatus discussed in the U.S. Court of Appeals for the Federal Circuit’s 2011 decision *In re Klein*.²³⁴ This invention has the advantage of mechanical simplicity, combined with the fractal complexities of a host of alternative embodiments.²³⁵ Section III.A describes the invention and patent application in the *Klein* case.²³⁶ Section III.B uses that example to show how the law governing

²²⁴ *Id.*

²²⁵ *Id.*

²²⁶ See *Bonito Boats, Inc. v. Thunder Craft Boats, Inc.*, 489 U.S. 141, 150–51 (1989) (“The federal patent system . . . embodies a carefully crafted bargain for encouraging the creation and disclosure of new, useful, and nonobvious advances in technology and design in return for the exclusive right to practice the invention for a period of years.”).

²²⁷ *Sitrick v. Dreamworks, LLC*, 516 F.3d 993, 999 (Fed. Cir. 2008).

²²⁸ See *Phillips v. AWH Corp.*, 415 F.3d 1303, 1321 (Fed. Cir. 2005) (en banc) (stating that the specification is the best guide to interpreting claim language).

²²⁹ 35 U.S.C. § 101 (2006); see *In re Fischer*, 421 F.3d 1365, 1371 (Fed. Cir. 2005) (stating that the invention must have “a significant and presently available benefit to the public”).

²³⁰ 35 U.S.C. § 101; *In re Nuijten*, 500 F.3d 1346, 1353–54 (Fed. Cir. 2007). As of September 16, 2011, “[N]o patent may issue on a claim directed to or encompassing a human organism.” 35 U.S.C.A. § 101 note (West 2001 & Supp. 2011).

²³¹ *Bilski v. Kappos*, 130 S. Ct. 3218, 3225 (2010).

²³² 35 U.S.C. § 102, amended by Leahy-Smith America Invents Act, Pub. L. No. 112-29, § 3(b)(1), (n), 125 Stat. 284, 285–87 (2011) (effective Mar. 16, 2013).

²³³ 35 U.S.C. § 103(a), amended by Leahy-Smith America Invents Act, Pub. L. No. 112-29, § 3(c), (n), 125 Stat. 284, 287, 293 (2011) (effective Mar. 16, 2013).

²³⁴ See 647 F.3d 1343, 1345–46 (Fed. Cir. 2011) (discussing the invention).

²³⁵ See *id.*

²³⁶ See *infra* notes 241–286 and accompanying text.

patent claims accommodates the fractal nature of invention.²³⁷ Section III.C explains the conflict between the enablement requirement of patent law and the fractal nature of invention.²³⁸ Section III.D explains how the same conflicts arise in the context of the written description requirement.²³⁹ Finally, Section III.E discusses how the prohibition on issuing patents for “abstract ideas” is particularly discordant with the fractal nature of invention.²⁴⁰

A. A Complex Patent for Simple Technology

Arnold Klein’s patent application U.S. 2006/0153000, published July 13, 2006, concerns the combination of sugar and water to make “nectar” for feeding birds and butterflies.²⁴¹ Hummingbirds require a mixture of one part sugar to four parts water, orioles require one part sugar to six parts water, and butterflies prefer a mixture that is one part sugar to nine parts water.²⁴² According to Mr. Klein, consumers need a simple device for combining sugar and water in the correct ratios.²⁴³ His solution is a mixing container with compartments to measure the ingredients in the desired proportions.²⁴⁴

The Klein application illustrates a number of distinct embodiments for accomplishing this task.²⁴⁵ One resembles a conventional mixing cup, but with straight sides incorporating three sets of vertical “rails” into which a divider may be inserted.²⁴⁶ These allow the container to be divided into the proportions needed for hummingbird, oriole, or butterfly nectar.²⁴⁷ After positioning the divider, the user of the device fills the smaller compartment with sugar and the larger with water.²⁴⁸ As long as the levels are the same, the ratio will be correct even

²³⁷ See *infra* notes 287–334 and accompanying text.

²³⁸ See *infra* notes 335–418 and accompanying text.

²³⁹ See *infra* notes 419–443 and accompanying text.

²⁴⁰ See *infra* notes 444–461 and accompanying text.

²⁴¹ U.S. Patent Application No. 11/363,714 (filed July 13, 2006), at [0003] [hereinafter Klein App.], available at http://www.google.com/patents/about/11_363_714_Convenience_nectar_mixing_and.html?id=SU-YAAAAEBAJ (click “Download PDF”).

²⁴² *Id.* at [0007–10].

²⁴³ *Id.* at [0006].

²⁴⁴ *Id.* at [0011].

²⁴⁵ *Id.* at [0014–61], figs.1–46.

²⁴⁶ *Id.* figs.1–7.

²⁴⁷ Klein App., *supra* note 241, at [0062].

²⁴⁸ *Id.* at [0063].

if the container is only partially filled.²⁴⁹ The user then removes the divider and mixes the nectar.²⁵⁰

An alternative embodiment relies on a cylindrical divider attached to the center of a round measuring cup.²⁵¹ Cylinders of different volumes provide the necessary ratios for hummingbird, oriole, or butterfly nectar.²⁵² The user fills the cylinder with sugar and the rest of the container with water.²⁵³ After matching the levels, the user pulls out the cylinder, allowing the sugar and water to mix.²⁵⁴ Other variants feature a rotating divider that the user can position to measure the proper amount of sugar, and then turn further to permit the sugar and water to combine.²⁵⁵ A less versatile embodiment consists of a cup with a fixed divider, positioned to supply the proportions necessary for only one of the nectar recipes.²⁵⁶ The user of this device fills the compartments, screws on a lid, and shakes the container to produce the finished product.²⁵⁷ Yet another embodiment accomplishes a similar result with separately molded compartments for sugar and water, rather than a single compartment divided by a partition.²⁵⁸ Finally, Klein discloses a measuring cup with a well at the bottom to hold a quantity of sugar and a larger space above to accommodate water.²⁵⁹ In this embodiment, the user simply fills the bottom with sugar to the level indicated, and then tops up the container with water.²⁶⁰ The mixing takes place as the user pours the water over the sugar.²⁶¹ The disadvantage of this simplest embodiment is that one must make a full container of nectar each time.²⁶²

For each of these distinct embodiments, Klein suggests variations.²⁶³ The removable divider may (or may not) be adapted as a stirring implement and lid.²⁶⁴ If used as a lid, the divider may include a

²⁴⁹ See *id.* (requiring the sugar and water to be filled to the same “line-of-sight” in each compartment).

²⁵⁰ *Id.* at [0064].

²⁵¹ *Id.* at [0065], figs.8–12.

²⁵² *Id.* at [0065].

²⁵³ Klein App., *supra* note 241, at [0065].

²⁵⁴ *Id.*

²⁵⁵ *Id.* at [0066], figs.13–16.

²⁵⁶ *Id.* at [0069], figs.35–42.

²⁵⁷ *Id.* at [0069].

²⁵⁸ *Id.* at [0070], figs.43–44.

²⁵⁹ Klein App., *supra* note 241, at [0071], figs.45–46.

²⁶⁰ *Id.* at [0071].

²⁶¹ *Id.*

²⁶² *Id.*

²⁶³ See *infra* notes 264–269 and accompanying text.

²⁶⁴ Klein App., *supra* note 241, at [0064].

hole that can be closed with an integral plug or a separate plug.²⁶⁵ The description of the rotating variant contemplates planar or contoured dividers.²⁶⁶ The dividers “may be made of a flexible or semi-flexible material and/or may have a reduced cross section at the edges to assist in sealing between the container compartments.”²⁶⁷ Figure 42 of the patent application depicts an alternative lid for the device designed to be shaken; this version includes a plug “connected to the lid . . . by an integrally formed strap.”²⁶⁸ Klein shows the last and simplest embodiment as a cylindrical cup, but it “could be made in many other functional shapes.”²⁶⁹

The specification concludes with the customary warning that even the many variations discussed do not encompass the full scope of the invention:

The foregoing description is not intended to be all inclusive of the embodiments that a CONVENIENCE NECTAR MIXING AND STORAGE DEVICE may have. The device itself, once disclosed, may be configured in a variety of embodiments that operate similarly to those detailed and described herein. I desire therefore, that my protection be limited, not by the constructions illustrated and described, but only by the proper scope of the appended claims.²⁷⁰

The application includes twenty-three claims, of which Claims 1, 12, and 19 are independent claims.²⁷¹ Claim 1 generally corresponds to the moveable divider embodiments.²⁷² The ten dependent claims that

²⁶⁵ *Id.*

²⁶⁶ *Id.* at [0068].

²⁶⁷ *Id.*

²⁶⁸ *Id.* at [0069], fig.42.

²⁶⁹ *Id.* at [0071].

²⁷⁰ Klein App., *supra* note 241, at [0075].

²⁷¹ *See id.* at 6, Claims 1–23.

²⁷² *Id.* at 6, Claim 1. Claim 1 reads as follows:

1. A convenience nectar mixing and storage device for use in the preparation of sugar-water nectar for feeding hummingbirds, orioles or butterflies, said device comprising:

a container that is adapted to receive water,

engagement means fixed or fitted to said container,

a divider adapted to be moveably held by said engagement means for forming a compartment within said container, wherein said compartment has a volume that is proportionately less than a volume of said container, by a ratio established for the formulation of sugar-water for hummingbirds, orioles or butterflies, wherein said compartment is adapted to receive sugar, and wherein

follow incorporate by reference all of the elements of Claim 1 and add one or two additional limitations.²⁷³ Claim 2, for example, limits the divider to one integrally formed with the container.²⁷⁴ Claim 3 includes a means to store the divider when not in use.²⁷⁵ Claim 8 specifies a container with a handle and pouring spout.²⁷⁶ Independent Claim 12, and its set of dependent claims, generally corresponds to the fixed-divider embodiments that are shaken to combine the ingredients.²⁷⁷ Independent Claim 19 corresponds to the embodiment in which pouring the water into the undivided container serves to mix the water with the pre-measured quantity of sugar.²⁷⁸

The technology is simple, yet the independent and dependent claims only begin to suggest the countless ways in which one could construct what Klein would call a “convenience nectar mixing and storage device.” Mapped as a branching fractal, one might begin with the main branches of moveable dividers, fixed dividers, and no dividers, represented in the three independent claims. Each of those could be made in many shapes, from many materials, and incorporating any number of features—handles, lids, vents, plugs, and more. The dividers could slide, tilt, swing, fold, flex, or retract. Piling variation upon variation, the coastline of even this modest fractal island is limitless.

Although we cannot tell from the application, both ascending and descending “cascades” may have played a role in building the nectar dispenser fractal to the stage reflected in the claims and disclosure. Klein likely had some general ideas about how the apparatus would work, and proceeded in “top-down” fashion to work out the details and variations. It is equally likely that Klein “backtracked” by reassessing solutions, eliminating unnecessary details, and returning to the big pic-

said divider is moveable from said engagement means allows mixing of said sugar and water to occur to provide said sugar-water nectar.

Id. The “engagement means” element would likely be construed as a means-plus-function element, covering any structure that performs the recited function (engagement) and that is equivalent to the structure (the “rails”) disclosed in the specification as performing that function. See 35 U.S.C. § 112, para. 6 (2006), amended by Leahy-Smith America Invents Act, Pub. L. No. 112-29, § 4(c), (e), 125 Stat. 284, 296–97 (2011) (effective Sept. 16, 2012) (stating that when a claim element is expressed as a means for performing a certain function, the claim shall cover the disclosed structure and equivalents thereof).

²⁷³ Klein App., *supra* note 24I, at 6, Claims 2–11.

²⁷⁴ *Id.* at 6, Claim 2.

²⁷⁵ *Id.* at 6, Claim 3.

²⁷⁶ *Id.* at 6, Claim 8.

²⁷⁷ See *id.* at 6, Claims 12–18 (requiring a “fixed divider”).

²⁷⁸ See *id.* at 6, Claim 19 (requiring that, when water is poured into the second compartment, it can mix with the sugar in the first compartment).

ture. Perhaps his first thoughts involved only the variation with the moveable divider, but on contemplating the advantages of a nectar shaken, not stirred, the fixed-divider alternative emerged as an attractive alternative. Invention is an “iterative process” in which understanding evolves gradually.²⁷⁹ As inventors translate their ideas into concrete embodiments—either working prototypes or the detailed disclosures required in a patent specification—broad conceptions become particularized.²⁸⁰ On the other hand, the exercise of drafting patent claims plays an important role in generalizing inventions. Before committing to a claim limitation, the inventor must be sure that it is necessary.²⁸¹ Too narrow a conception of how the invention may be implemented gives competitors an easy way to avoid the patent.²⁸²

To recall the Koch island analogy, adding details to a general conception is the equivalent of extending new promontories from an existing root. If the movable divider embodiment of the nectar-mixing apparatus is one promontory, imagining a planar shape for that moveable divider extends a sub-promontory, adapting it as a lid extends a sub-sub-promontory, and so on. Realizing that the moveable divider need not be planar but could be cylindrical is the equivalent of *stepping back* and extending a new promontory, itself subject to branching, in an entirely different direction. Abandoning the idea that the divider has to be moveable at all is a further step back, opening up even more possibilities. Generalizing in this fashion is the equivalent of constructing a Koch island *backwards*.²⁸³

²⁷⁹ PALEY, *supra* note 130, at 171.

²⁸⁰ See *id.* (describing the process of invention as a “journey from idea to concrete reality”).

²⁸¹ See Michael J. Meurer & Craig Allen Nard, *Invention, Refinement and Patent Claim Scope: A New Perspective on the Doctrine of Equivalents*, 93 GEO. L.J. 1947, 1976–77 (2005) (discussing how the inventor of a tennis racket “should describe the material used to make his racket in general terms” so that the claims “will literally cover a racket of the same shape and dimension even if it is made from a substance that was not known at the time of the patent application”).

²⁸² See ALAN L. DURHAM, *PATENT LAW ESSENTIALS: A CONCISE GUIDE* 21 (3d ed. 2009) (explaining that, because the claim language defines the scope of a patent, using language that limits the scope of the claim will also limit the protection provided by the patent).

²⁸³ As Jeanne Fromer has observed, an inventor looking to draft an adequate patent claim must “think[] beyond the particular creation . . . to abstract principles or patterns underlying the creation and a range of potential commercial possibilities.” Fromer, *supra* note 217, at 757. The inventor of a metal doorstop, for example, “will have to think about whether doorstops in other materials embody the same concept and whether the invention can be used for other purposes.” *Id.* Fromer identifies the “process of conceptual and commercial abstraction” as a cost imposed by our system of peripheral claiming. *Id.* But abstraction is indispensable to technological advancement. The inventor of the metal

Eventually the inventor seeking a patent must complete the patent application, bringing the growth of this fractal to an end as far as the claims and disclosure are concerned. As far as the invention itself is concerned, the fractal has no end. Further exploration reveals more latent possibilities.

If a fractal structure like a Koch island is a fair representation of the realities of technological progress, the question we must now ask is whether the basic rules of patent law are compatible with that structure. As discussed in the remainder of this Section, a number of persistent controversies in patent law relate to the difficulty of reducing a complex network of technological relationships, like those illustrated in the Klein application, into the thing known in patent law as “the invention.” We will consider, in turn, the obstacles raised by fractal invention in fixing the scope of the patent,²⁸⁴ in enabling and describing the invention,²⁸⁵ and in avoiding patents to abstract ideas.²⁸⁶

B. Claiming the Fractal Invention

In the case of any patent, there are a number of ways to define “the invention.” One is the idea within the contemplation of the inventor. In the context of distinguishing between concepts and concrete embodiments, the U.S. Supreme Court, in the 1998 case *Pfaff v. Wells Electronics, Inc.*, stressed that “[t]he primary meaning of the word ‘invention’ in the Patent Act unquestionably refers to the inventor’s conception”²⁸⁷ The Federal Circuit has defined “conception” as the formation in the mind of the inventor of “a definite and permanent idea of an operative invention, including every feature of the subject matter sought to be patented.”²⁸⁸ A second candidate for “the invention” is the technological advancement disclosed in the patent specification. Section 112 of the Patent Act requires the specification to include “a written description of the invention” and disclosures adequate

doorstop *should* consider alternatives. The exercise of reducing an invention to its essentials in order to describe it in a claim may lead the inventor, and eventually the public, to a better understanding of the invention.

²⁸⁴ See *infra* notes 287–334 and accompanying text.

²⁸⁵ See *infra* notes 335–443 and accompanying text.

²⁸⁶ See *infra* notes 444–461 and accompanying text.

²⁸⁷ 525 U.S. 55, 60 (1998).

²⁸⁸ *Sewall v. Walters*, 21 F.3d 411, 415 (Fed. Cir. 1994); see also *Shum v. Intel Corp.*, 499 F.3d 1272, 1277 (Fed. Cir. 2007) (“Conception is the formation in the mind of the inventor of a definite and permanent idea of the complete and operative invention, as it is hereafter to be applied in practice.” (internal quotations omitted)).

to allow persons skilled in the art “to make and use the same.”²⁸⁹ This measure of “the invention” is in keeping with the patentee’s bargain of disclosure in exchange for exclusive rights. A third candidate for “the invention” is the set of all things that, if unauthorized, infringe the patent—all things, in other words, that possess each of the elements recited in one patent claim. In the 2005 en banc case *Phillips v. AWH Corp.*, the Federal Circuit declared it “a ‘bedrock principle’ of patent law that ‘the claims of a patent define the invention to which the patentee is entitled the right to exclude.’”²⁹⁰

Nothing in the Patent Act suggests that the invention conceived by the inventor, described in the specification and claimed in the claims, is not one and the same thing. So it should be, if what entitles the patentee to exclude others is having thought of the invention first and disclosed it fully in a patent application.

The problem is that claims accommodate the fractal nature of invention in ways that contemplation and disclosure cannot. No one can completely describe, or fully contemplate, the contours of any portion of a fractal. The details reveal themselves to those who look, *as they look*. Nevertheless, one can define, without ambiguity, a portion of a fractal in order to distinguish it from the rest. In the case of a Koch island, one can refer to that portion of the island rooted in what begins as the uppermost point at the Star of David stage. Defining a portion of the irregular Mandelbrot set is more difficult, but software users who magnify a portion of the figure by specifying a narrower set of starting values do exactly that.²⁹¹ They cannot not tell what they will see as they “zoom in” further, but they can tell what portion of the Mandelbrot set they are investigating. One option is simply to circle a portion of a fractal to distinguish the part that lies within. Claims, in similar fashion, define a portion of the network of technological advancement, even if they do not describe every variation they encompass.

Claim 1 of Klein’s application has three elements—a water-receiving container, an “engagement means” to hold the divider, and a movable divider to form compartments in the container that correspond to the correct sugar-water ratios.²⁹² Any one of the infinite variety of nectar-mixing apparatus with those three elements falls within the scope of

²⁸⁹ 35 U.S.C. § 112, para. 1 (2006), *amended by Leahy-Smith America Invents Act*, Pub. L. No. 112-29, § 4(c), (e), 125 Stat. 284, 296–97 (2011) (effective Sept. 16, 2012).

²⁹⁰ 415 F.3d 1303, 1312 (Fed. Cir. 2005) (en banc) (quoting *Innova/Pure Water, Inc. v. Safari Water Filtration Sys., Inc.*, 381 F.3d 1111, 1115 (Fed. Cir. 2004)).

²⁹¹ See *supra* notes 56–59 and accompanying text.

²⁹² Klein App., *supra* note 241, at 6, Claim 1.

Claim 1.²⁹³ Like most claims, Klein's claim is open ended.²⁹⁴ Because the preamble ends with the word "comprising," nectar-mixing cups that have the three recited elements infringe, whether or not they have additional elements too.²⁹⁵ To put things in algebraic terms, the claim covers the set of all objects that include A, B, and C, regardless of whether those objects also include X, Y, or Z. The way claims work matches well with the fractal nature of invention. If one promontory of Klein's invention consists of nectar-mixing containers with dividers that are (A) movable, (B) planar, and (C) adapted to function as a lid, then a claim with those elements (A, B, C) covers that promontory and all of its separately indescribable appendages.

Difficulties still arise because of the ambiguities of language. Some of Klein's claims refer to a "lid."²⁹⁶ One can imagine a case in which an accused product had a top that only partially covered the contents of the container. Klein might call that a "lid" and the accused infringer might disagree. The problem here would not arise from the fractal complexities of invention, but from the difficulty of using language to clearly specify the promontory, or sub-promontory, to which the claims refer. When claim language is ambiguous, one can look for assistance to the disclosures of the patent specification.²⁹⁷ If Klein always referred to a "lid" as a precaution to avoid spills, the ambiguity might be resolved.

C. *The Arlington Dissent*

Although it is a "bedrock principle" of patent law that the claims—not the examples in the specification—determine the scope of the patentee's right to exclude,²⁹⁸ there remains some controversy about interpreting claims so generously that they exceed the scope of "the invention," meaning the technology that the inventor actually

²⁹³ See DURHAM, *supra* note 282, at 21 (explaining that a claim covers any object that includes each element described in the claim).

²⁹⁴ See PETER P. MERGES ET AL., *INTELLECTUAL PROPERTY IN THE NEW TECHNOLOGICAL AGE* 299 (5th ed. 2010) (stating that most claims use open-ended language, so that they can encompass infringing products that include additional elements not anticipated by the patentee).

²⁹⁵ See *Free Motion Fitness, Inc. v. Cybex Int'l, Inc.*, 423 F.3d 1343, 1353 (Fed. Cir. 2005) (holding that an infringing product cannot avoid the scope of a claim by adding additional elements if the claim contains an open phrase like "comprising"); Collins, *supra* note 186, at 530–31 (indicating that use of the word "comprising" in a claim will allow that claim to encompass products with additional elements).

²⁹⁶ Klein App., *supra* note 241, at 6, Claims 4–6, 12, 23.

²⁹⁷ See *Phillips*, 415 F.3d at 1315–16 (explaining how courts may "rely heavily on the written description for guidance as to the meaning of the claims").

²⁹⁸ *Id.* at 1312.

contemplated and disclosed. The 2011 Federal Circuit case of *Arlington Industries, Inc. v. Bridgeport Fittings, Inc.* illustrates this tension.²⁹⁹

The invention in *Arlington* concerned an electrical connector to plug a cable into a junction box.³⁰⁰ Plugging in a cable is usually a two-hand job—one hand to hold the cable and the other to screw in a threaded lock nut.³⁰¹ The patent covered an improved push-on connector that is more easily installed.³⁰² The claim element in dispute called for a “spring metal adapter.”³⁰³ The patent specification depicted the adapter as a metal cylinder with a gap or split along its length.³⁰⁴ The issue before the court was whether the claim element “spring metal adapter” should be limited to the split-ring configuration.³⁰⁵ Although the district court found that, without a split, an adapter could not “spring” as the claim required,³⁰⁶ the Federal Circuit concluded that “spring metal” referred simply to the material from which the adapter is made.³⁰⁷

The court observed that “[w]hile the drawings of the adapter consistently depict an incomplete circle, drawings in a patent need not illustrate the full scope of the invention.”³⁰⁸ Based on a variety of clues, including references in the specification to “spring steel” as a typical material for the adapter, the court concluded that a “spring metal adapter” must be made from “spring metal,” but it need not be split as depicted in the patent specification.³⁰⁹ The specification, the Federal Circuit ruled, “does not delimit the right to exclude.”³¹⁰ Delimiting the right to exclude is the function of the claims alone.³¹¹

²⁹⁹ See 632 F.3d 1246, 1258 (Fed. Cir. 2011) (Lourie, J., concurring in part and dissenting in part) (interpreting the claims to cover only what the patentees disclosed in the specification, as that indicates the full scope of what they “invented”). Although Judge Alan Lourie’s opinion in *Arlington* was a concurrence in part and dissent in part, this Article focuses on the dissenting portion of his opinion and, therefore, refers to his opinion as a “dissent” in the main text.

³⁰⁰ *Id.* at 1249 (majority opinion).

³⁰¹ See *id.* (stating that the prior art design required two hands to connect).

³⁰² *Id.*

³⁰³ *Id.* at 1248, 1250.

³⁰⁴ See *id.* at 1251 (reproducing an illustration from the patent).

³⁰⁵ *Arlington*, 632 F.3d at 1248–49.

³⁰⁶ *Id.* at 1252.

³⁰⁷ See *id.* at 1253–56 (interpreting the language of the claim to require that the adapter be made of spring metal).

³⁰⁸ *Id.* at 1254.

³⁰⁹ *Id.* at 1253–56.

³¹⁰ *Id.* at 1256.

³¹¹ *Arlington*, 632 F.3d at 1256.

Judge Alan Lourie dissented from the majority's claim construction.³¹² In his view, the specification is "the heart of the patent,"³¹³ and it serves a primary role in interpreting claim language because "the specification describes what the inventors invented."³¹⁴ In "colloquial terms," he wrote, "you should get what you disclose."³¹⁵ For Judge Lourie, "the invention" is whatever the patentee "contemplated."³¹⁶ In this case, the inventors disclosed split-ring adapters and no other kind.³¹⁷ Based on this evidence, "the inventors . . . contemplated that their invention consisted only of spring metal adapters with an opening that results from not forming a complete circle."³¹⁸ Though Judge Lourie agreed that the claims measure the patentee's right to exclude, he would put more emphasis on construing claims to reflect "what the inventors meant when they used the language they did."³¹⁹ "The bottom line of claim construction," he concluded, is that "the claims should not mean more than what the specification indicates, in one way or another, the inventor invented."³²⁰

The proper role of the specification in interpreting claim language has always been difficult to articulate. According to black-letter law, one

³¹² See *id.* at 1257 (Lourie, J., concurring in part and dissenting in part) (concurring with the majority's ruling regarding one of the patents at issue, but dissenting in regard to the majority's interpretation of the claim requiring "spring metal adapters").

³¹³ *Id.*

³¹⁴ *Id.*

³¹⁵ *Id.*

³¹⁶ See *id.* at 1257–58 (lamenting the use of patents to block innovations by competitors). Judge Lourie stated:

Unfortunately, the nature of our adversary system often causes . . . patents to be asserted against someone engaged in activity not contemplated by the inventors as part of their invention. So the patent is used as a business weapon against such parties, and litigation counsel attempt to fit a square peg into a round hole, or, in other words, to fit into the claim language what the inventors never contemplated as a part of their invention.

Id.

³¹⁷ *Arlington*, 632 F.3d at 1258 (Lourie, J., concurring in part and dissenting in part).

³¹⁸ *Id.*

³¹⁹ *Id.*

³²⁰ *Id.* The majority rejected Judge Lourie's "you should get what you disclose" remark as "devalu[ing] the importance of claim language in delimiting the scope of legal protection." *Id.* at 1255–56 n.2 (majority opinion). A patent specification "discloses and teaches" only the claims "define and circumscribe." *Id.* (quoting *Ariad Pharms., Inc. v. Eli Lilly & Co.*, 598 F.3d 1336, 1347 (Fed. Cir. 2010) (en banc)); *infra* notes 321–324 and accompanying text. In other "colloquial term[s]," the majority wrote, "the name of the game is the claim." *Id.* (quoting Giles S. Rich, *The Extent of the Protection and Interpretation of Claims—American Perspectives*, 21 INT'L REV. INDUS. PROP. & COPYRIGHT L. 497, 499, 501 (1990)).

can use the specification to interpret claim language,³²¹ but one cannot import into the claims limitations that appear only in the specification.³²² In practice, just a “fine line” separates the two.³²³ That the specification in *Arlington* depicts split-ring adapters is no reason to introduce “split-ring adapter” as a claim limitation; it might, however, be a reason to interpret “spring metal adapter” in a limited fashion.³²⁴ What is interesting about *Arlington* is not that Judge Lourie’s interpretation of “spring metal adapter” differed from that of the majority, but rather that Judge Lourie stressed a unitary invention—one invention contemplated, disclosed, and successfully claimed.³²⁵ The majority, in contrast, distinguished between the disclosed invention and the scope of the inventor’s exclusive rights.³²⁶

The fractal nature of invention supports the majority’s view. A claim can define a portion of the branching structure and establish exclusive rights to all that it contains, but the inventor cannot contemplate, or disclose, every variation within its scope. The fractal properties of multiplicity and latency make that impossible.³²⁷ Suppose that the inventors in *Arlington* were limited to split-ring adapters because that was the only kind of “spring metal adapter” they contemplated. There

³²¹ See *Phillips*, 415 F.3d at 1321 (specification is “the single best guide to the meaning of a disputed term”).

³²² See *id.* at 1323 (“[A]lthough the specification often describes very specific embodiments of the invention, we have repeatedly warned against confining the claims to those embodiments.”); *Teleflex, Inc. v. Ficosa N. Am. Corp.*, 299 F.3d 1313, 1326 (Fed. Cir. 2002) (“[L]imitations from the specification are not to be read into the claims . . .”).

³²³ *Arlington*, 632 F.3d at 1255.

³²⁴ See *id.* (explaining the difference between reading a claim in light of the specification and importing a limitation from the specification into a claim).

³²⁵ See *id.* at 1257 (Lourie, J., concurring in part and dissenting in part) (indicating that the specification describes what the patentee invented and that the claims must correspond to what has been invented and disclosed).

³²⁶ See *id.* at 1255 & n.2 (majority opinion) (contrasting reading a claim in light of the specification with importing a limitation from the specification into a claim).

³²⁷ One scholar discusses the seeming paradox of claims that must be fixed in meaning as of their filing date, but that “grow” to encompass after-arising infringing technology, and finds no contradiction. Collins, *supra* note 186, at 513. A coarse-grained description of the contents of the claim (leaving out details that make the after-arising technology different) need not change, even as the fine-grained details of the things themselves evolve. *Id.* at 518–20. Within the context of the fractal structure of invention, one could say that the promontory distinguished by the presence of the claim elements remains the same promontory, even as the variations within that promontory—the wrinkles on the coastline—reveal themselves over time. One would not say that a mathematical fractal, like the Mandelbrot set, “grows”; what grows is our understanding as we peer more closely at its perimeter. That is one way to look at invention. In any event, so long as the role of claims is to distinguish a portion of the fractal from the rest, they can embrace technologies unknown to the inventor without changing their meaning.

must be numerous varieties of split-ring adapters employing different shapes and materials. If the inventors “contemplated” only the one illustrated in the patent specification, would their claim be further limited?

Limiting claims to what the inventor “contemplated” leads to confusion. An inventor can contemplate finished embodiments, but a patent cannot be limited to those without reducing its value dramatically.³²⁸ An inventor can contemplate a general idea—like the general idea of a push-on cable connector—but contemplation at that level was not what Judge Lourie had in mind. The issue is how far up or down the fractal chain, to what level of specificity, the inventor’s contemplation must go. An inventor knows there are always other ways to do the same thing. That is the reason for cautionary language, like that found in the Klein application, warning that the disclosed embodiments are merely examples.³²⁹ At what level of detail must the inventor contemplate those alternatives in order to claim them?

The simplest way to deal with this issue is to ignore it, as far as claim interpretation is concerned. If a claim is simply a warning to others of the territory that belongs to the patentee, the question is how the language of the claim would be understood by persons skilled in the art. What the inventor contemplated, as revealed in the disclosures of the specification, is relevant to how one should interpret claim language that would otherwise be ambiguous. The issue, however, is ultimately one of understanding what the claim says, not ensuring balance in the patent bargain—in other words, that “you . . . get what you disclose.” This was the view of the *Arlington* majority and, in spite of his rhetoric, even Judge Lourie ultimately resorted to what is simply a different interpretation of the phrase “spring metal adapter.” If the inventor believed that a split-ring design was the only alternative, and the disclosure showed that to be the case, then a narrow interpretation would be justified.³³⁰

³²⁸ See *Festo Corp. v. Shoketsu Kinzoku Kogyo Kabushiki Co.*, 535 U.S. 722, 732 (2002) (explaining that the doctrine of equivalents in patent law prevents claim avoidance by “unimportant and insubstantial changes and substitutions.” (quoting *Graver Tank & Mfg. Co. v. Linde Air Prods. Co.*, 339 U.S. 605, 607 (1950))). In the context of copyright, Judge Learned Hand warned against rights limited to the text itself—rights that plagiarists could easily avoid through “immaterial variations.” *Nichols v. Universal Pictures Corp.*, 45 F.2d 119, 121 (2d Cir. 1930).

³²⁹ See *supra* note 270 and accompanying text.

³³⁰ Some scholars have advocated a re-emphasis of central claiming, so that courts setting the boundaries of a patent can concentrate on “what the patentee actually invented,” rather than the meaning of terminology invented by lawyers. Burk & Lemley, *supra* note

It is a principle of our patent system to expect disclosure in exchange for rights, and to award those rights based on invention.³³¹ If we had a patent system in which there was no such bargain, claim interpretation would be the only relevant consideration. Patentees could be assigned their exclusive territories not in exchange for disclosure, or even in recognition of their discoveries, but simply to ensure that those territories are managed efficiently. Edmund Kitch's "prospect theory" of patent law suggests that such a system would be rational.³³² As discussed above, this system would adequately accommodate the fractal nature of invention.³³³ The fractal nature of invention, however, creates problems for the "bargain" envisioned by U.S. patent law through the discord of what can be contemplated, disclosed, and claimed. Judge Lourie's concerns, therefore, cannot be ignored. Recently, the Federal

216, at 1787-88. In a system of central claiming, courts can be flexible in setting patent boundaries, taking into account the significance of the invention and how much it differs from the prior art. *See id.* at 1746 (describing the court's discretion under a central claiming system). Judge Lourie would probably approve. A central claiming approach might avoid the inherent difficulties of describing an invention in claim language, but it would bring into the infringement inquiry all of the problems that stem from the fractal structure of technological progress. Based on the examples and disclosure presented in the specification, one would have to determine how far up the fractal network the patentee can justifiably stake a claim.

Other disciplines of intellectual property follow a similar approach. *Id.* at 1774. In copyright, the text itself serves as the "core" of the author's rights; the boundaries depend on how different an accused work can be while remaining "substantially similar" in expression. *Id.* Patents have one advantage over copyrights—the existence of the disclosure, in which the inventor can provide information relevant to the significance of the invention and its place in the art. Nevertheless, one cannot be optimistic that a central claiming approach would make the boundaries of patents easier to discern. If anything, the fractal structure of invention suggests that a peripheral system is a more efficient way to set off a domain of exclusive rights. One can define a portion of a Koch island much more easily by circling it (a rough analog of a peripheral claim) than by describing representative examples on the infinitely complex periphery. A system of central claiming would confront, in the realm of infringement, the problem of patentees claiming broader exclusive rights than their contributions to the art can support. As discussed below, courts today generally address this through the enablement and written description requirements, and that is likely to remain the case for the foreseeable future. *See infra* notes 331-443 and accompanying text.

³³¹ *See Bonito Boats*, 489 U.S. at 150-51 ("The federal patent system . . . embodies a carefully crafted bargain for encouraging the creation and disclosure of new, useful, and nonobvious advances in technology and design in return for the exclusive right to practice the invention for a period of years.")

³³² *See* Edmund W. Kitch, *The Nature and Function of the Patent System*, 20 J.L. & ECON. 265, 276 (1977) ("[A] patent 'prospect' increases the efficiency with which investment in innovation can be managed."). Prospect theory imagines a legal system in which exclusive rights to explore certain defined areas of technology are granted to potential inventors prior to making their discoveries. *Id.*

³³³ *See supra* notes 325-330 and accompanying text.

Circuit has dealt with those concerns primarily through the enablement and written description requirements.³³⁴

D. *Enabling the Fractal Invention*

Section 112 of the Patent Act requires disclosures in the patent specification sufficient to enable any person skilled in the art to make and use the invention without “undue experimentation.”³³⁵ If Klein’s “invention” encompassed all nectar-mixing devices within the scope of his claims, and the Klein application left out some information that persons skilled in the art would need to complete *any* nectar-mixing apparatus (a gap that could not be filled with knowledge already possessed by persons skilled in the art), the specification would be non-enabling.³³⁶ A more interesting situation arises if Klein’s disclosure enables the construction of some, but not all, of the nectar-mixing devices within the scope of his claims. Klein admits that his invention may be practiced in ways that are not disclosed.³³⁷ The measuring cups, for example, may be made in an infinite variety of shapes, not all of which are, or could be, described. Some variations would not require “undue experimentation” to achieve, but others undoubtedly would. One merely has to imagine mixing devices within the scope of Klein’s open-ended claims, but made from materials unknown to science.

In a series of recent cases, in which Judge Lourie played a prominent role, the Federal Circuit held that, when a claim encompasses more than one variation of the same invention, a disclosure that enables only some variations may be inadequate.³³⁸ The breadth of the disclosure has to match the breadth of the claims.³³⁹ On its face, that is a principle in keeping with the “bargain model” of the patent system. In practice, the fractal properties of invention make that principle difficult to apply.

³³⁴ See *infra* notes 335–443 and accompanying text.

³³⁵ *Sitrick*, 516 F.3d at 999; see also 35 U.S.C. § 112, para. 1 (2006), amended by Leahy-Smith America Invents Act, Pub. L. No. 112-29, § 4(c), (e), 125 Stat. 284, 296–97 (2011) (effective Sept. 16, 2012) (“The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, . . . to make and use the same . . .”).

³³⁶ See *Sitrick*, 516 F.3d at 999 (requiring that a patentee disclose enough information to enable someone skilled in the art to make or use it without undue experimentation).

³³⁷ See *supra* note 270 and accompanying text.

³³⁸ See *infra* notes 340–377 and accompanying text.

³³⁹ See *infra* notes 377–400 and accompanying text.

1. Partial Enablement

The first of those recent cases was the 2003 Federal Circuit case *AK Steel Corp. v. Sollac*, in which the invention concerned hot-dipped, aluminum-coated stainless steel.³⁴⁰ The patent specification explained that Type 1 aluminum coatings, which are composed of about ten percent silicon, do not adhere well to the steel substrate.³⁴¹ The inventors, therefore, recommended a purer Type 2 aluminum coating.³⁴² As originally filed, the claims were limited to a coating “consisting essentially of aluminum,” but the inventors later sought and obtained broader claims.³⁴³ In an opinion authored by Judge Lourie, the Federal Circuit determined that the broader claims covered both Type 1 and Type 2 aluminum.³⁴⁴ The issue then was whether the specification enabled the claimed invention.³⁴⁵

Although the specification enabled the use of Type 2 aluminum, “as part of the *quid pro quo* of the patent bargain, the applicant’s specification must enable one of ordinary skill in the art to practice the full scope of the claimed invention.”³⁴⁶ When the claims cover a range of variations, the specification must supply “reasonable enablement of the scope of the range.”³⁴⁷ This does not mean that the specification “must necessarily describe how to make and use every possible variant of the claimed invention.”³⁴⁸ The knowledge already possessed by persons skilled in the art, plus routine experimentation, “can often fill gaps, interpolate between embodiments, and perhaps even extrapolate beyond the disclosed embodiments, depending upon the predictability of the art.”³⁴⁹ In this case, no such “gap filling” could make up for the failure of the specification to enable the use of Type 1 aluminum.³⁵⁰ The specification was not merely silent on the matter, it “clearly and strongly warn[ed]” that Type 1 aluminum should be avoided.³⁵¹ Because the

³⁴⁰ 344 F.3d 1234, 1236, 1245 (Fed. Cir. 2003) (holding that the specification failed to enable some of the claimed subject matter).

³⁴¹ *Id.*

³⁴² *Id.* at 1236–37.

³⁴³ *Id.* at 1237.

³⁴⁴ *Id.* at 1241–43.

³⁴⁵ *Id.* at 1243.

³⁴⁶ *AK Steel*, 344 F.3d at 1244.

³⁴⁷ *Id.*

³⁴⁸ *Id.*

³⁴⁹ *Id.*

³⁵⁰ *See id.* (finding the specification inadequate).

³⁵¹ *Id.*

specification did not enable “a significant portion of the subject matter encompassed by the contested claims,” those claims were invalid.³⁵²

A similar case decided by the Federal Circuit in 2004, *Liebel-Flarsheim Co. v. Medrad, Inc.*, involved a device used to inject fluids during medical procedures.³⁵³ The embodiments disclosed in the patents included pressure jackets around the syringes to contain the pressurized fluids.³⁵⁴ Although none of the asserted claims referred to a pressure jacket, the district court interpreted the claims to require one.³⁵⁵ The Federal Circuit reversed.³⁵⁶ During prosecution, the patentee had removed references to pressure jackets from the claims in order to cover jacketless devices like the defendant’s.³⁵⁷ To restore pressure jackets to the claims by implication would be to ignore the patentee’s clearly expressed intentions.³⁵⁸

On remand, the district court held the newly interpreted claims invalid for lack of enablement and, when the case returned to the Federal Circuit, that finding was affirmed.³⁵⁹ In an opinion authored by Judge Lourie, the court remarked on “the irony of this situation”; having won a broad claim construction that did not require pressure jackets, the patentee “then had to show that such a claim was fully enabled, a challenge it could not meet.”³⁶⁰ The specification warned that injectors without pressure jackets would be expensive and impractical for disposable syringes.³⁶¹ All of the illustrations depicted injectors with pressure jackets.³⁶² Contradicting the argument that pressure jackets could be eliminated without undue experimentation, the inventors admitted that they had failed in their own attempts to build injectors without pressure jackets before abandoning the effort as “too risky.”³⁶³ As in *AK Steel*, the specification failed to provide “reasonable enablement of the scope of the range”—the “range” here including injectors with and without pressure jackets.³⁶⁴

³⁵² *AK Steel*, 344 F.3d at 1245.

³⁵³ *Liebel-Flarsheim Co. v. Medrad, Inc.*, 358 F.3d 898, 900 (Fed. Cir. 2004).

³⁵⁴ *Id.* at 901.

³⁵⁵ *Id.*

³⁵⁶ *Id.* at 903.

³⁵⁷ *Id.* at 909.

³⁵⁸ *Id.*

³⁵⁹ *Liebel-Flarsheim Co. v. Medrad, Inc. (Liebel-Flarsheim II)*, 481 F.3d 1371, 1375, 1378 (Fed. Cir. 2007).

³⁶⁰ *Id.* at 1380. “The motto, ‘beware of what one asks for,’ might be applicable here.” *Id.*

³⁶¹ *Id.* at 1379.

³⁶² *Id.*

³⁶³ *Id.*

³⁶⁴ *Id.* at 1380 (quoting *AK Steel*, 344 F.3d at 1244).

In *Automotive Technologies International, Inc. v. BMW of North America, Inc.*, a Federal Circuit case decided in 2007, Judge Lourie authored a third opinion focusing on the scope of enablement.³⁶⁵ The invention here was a side-impact sensor for activating an airbag in the event of a vehicle collision.³⁶⁶ Prior art sensors deployed the airbag when crushed or deformed.³⁶⁷ The sensor in this case detected the acceleration of a movable mass within the sensor housing.³⁶⁸ With infringement in mind, the patentee successfully argued in favor of a broad claim construction that included both mechanical switch assemblies, like those depicted in the patent specification, and electronic switch assemblies.³⁶⁹ As in *Liebel-Flarsheim*, the unintended result was a claim held invalid for lack of enablement.³⁷⁰

In this case, the patent did not discourage the use of electronic switches.³⁷¹ In fact, it included a “conceptional view” of an electronic sensor assembly, including a sensor mass and housing,³⁷² and it stated that acceleration of the mass could be detected “by a variety of technologies using, for example, optics, resistance change, capacitance change, or magnetic reluctance change.”³⁷³ Nevertheless, the patent described the electronic switch in such a cursory fashion—the “conceptual view” omitting any disclosure of structure or circuitry—that a person of ordinary skill in the art could not have made one without undue experimentation.³⁷⁴ The patentee’s claim that acceleration sensors represented a “breakthrough” for side-impact airbag deployment reinforced that impression.³⁷⁵ Once again, the patent failed to provide “rea-

³⁶⁵ 501 F.3d 1274, 1276, 1282, 1285 (Fed. Cir. 2007) (holding claims invalid for lack of enablement).

³⁶⁶ *Id.* at 1276–77.

³⁶⁷ *Id.* at 1277.

³⁶⁸ *Id.* at 1277–78.

³⁶⁹ *Id.* at 1280, 1283.

³⁷⁰ *See id.* (affirming the lower court’s holding that the claim, as broadly construed, was invalid for lack of enablement); *Liebel-Flarsheim II*, 481 F.3d at 1380 (noting that, ironically, the court was persuaded by the patentee to interpret the claim broadly, which forced it to invalidate the claim for lack of enablement).

³⁷¹ *See Auto. Techs.*, 501 F.3d at 1278 (describing the portion of the specification that discloses the use of an electronic sensor instead of a mechanical one).

³⁷² *Id.*

³⁷³ *Id.*

³⁷⁴ *Id.* at 1282–83.

³⁷⁵ *See id.* at 1283 (stating that, since this technology is a breakthrough, a more thorough explanation of it would be required to enable its use by one skilled in the art). “Given that side impact sensing was a new field and that there were no electronic sensors in existence that would detect side impact crashes, it was especially important for the specifi-

sonable enablement of the scope of the [claimed] range.”³⁷⁶ Electronic sensors, the court concluded, are “not just another known species of a genus consisting of sensors, but are a distinctly different sensor compared with the well-enabled mechanical side impact sensor that is fully discussed in the specification.”³⁷⁷

2. “Reasonable” Enablement

The fractal properties of invention would not intrude if it were enough to enable a single embodiment within the claimed range. Although the path of invention may be tortuous, an inventor can achieve a completed embodiment and can disclose to others how to make and use that embodiment without undue experimentation. The Klein application appears to enable several variants.³⁷⁸ On the other hand, if one must enable enough embodiments to match the “range” covered by the claim, the fractal nature of invention makes matters much more difficult. Thanks to the branching structure of invention, even the simplest idea leads to a vast array of variations. These cannot all be disclosed in the specification, nor can one entirely “fill in the gaps” by relying on the knowledge of those skilled in the art and the fruits of routine experimentation.³⁷⁹ Unless the Klein application discloses the *ultimate* nectar-mixing device, there will always be room for significant

cation to discuss how an electronic sensor would operate . . . and to provide details of its construction.” *Id.* at 1284.

³⁷⁶ *Id.* at 1285 (quoting *Liebel-Flarsheim II*, 481 F.3d at 1380).

³⁷⁷ *Auto. Techs.*, 501 F.3d at 1285. As proof that this approach to enablement is not the sole province of Judge Lourie, a Federal Circuit panel in which he was not included issued a similar opinion. See *Sitrick*, 516 F.3d at 999–1000, 1002–03 (holding a claim invalid when partially, but not fully, enabled). In *Sitrick v. Dreamworks*, the technology involved inserting a user’s image into a preexisting video. *Id.* at 995. The claims encompassed inserting images in both videogames and movies, but the specification only enabled the former. *Id.* at 999–1000. Altering a movie involved an entirely different set of problems, and because the specification did not teach how to solve them without undue experimentation, it failed to enable the full scope of the invention. *Id.*

³⁷⁸ See Klein App., *supra* note 241, at [0062–75] (describing many variations on the “convenience nectar mixing and storage device(s)”).

³⁷⁹ Some scholars identify the impossibility of enabling all variations within the scope of a claim as a shortcoming of peripheral claiming system. Burk & Lemley, *supra* note 216, at 1764–65. I would go further. The multiplicity of embodiments that cannot be enabled is a consequence of the fractal structure of invention and would persist even in a system of central claiming. The only way to avoid the problem would be to define the invention as whatever the patentee enables. In such a system, improvements, because they are improvements, would not infringe. This would be very different than our current system and might provide inadequate incentives to develop and disclose basic inventions.

changes, even within the boundaries set by the claims. According to Petroski, "There can be no such thing as a 'perfected' artifact . . ." ³⁸⁰

Consider the sensors discussed in *Automotive Technologies*.³⁸¹ The court calls the mechanical sensor "well-enabled" and "fully disclosed."³⁸² The patent does disclose, in great detail, one variety of mechanical sensor, in which the forces of a collision cause a "flapper" to move until it closes an electrical circuit and initiates airbag deployment.³⁸³ The specification also teaches that other mechanical sensors, including spring-mass sensors and viscously damped sensors, may be substituted.³⁸⁴ Many such mechanical sensors might be within the reach of a person skilled in the art without undue experimentation, but it is difficult to believe that *all* of them would be. Suppose someone later devised a mechanical sensor based on the movement of an electrically conductive fluid. A fluid-based sensor might be a great innovation, worthy of a patent of its own. Would the failure to enable it make the patent in *Automotive Technologies* invalid? Or, if the patentee had fully disclosed *one* version of an electronic sensor, would the failure to disclose others—based on laser interferometry, radar, sonar, or some other exotic technology—have mattered?

The answer must lie in what the court means by "reasonable enablement" of the scope of the claimed range of embodiments.³⁸⁵ One possibility is to say that "reasonable" enablement means enabling a certain proportion of all of the variations that fall within the scope of the claim. Yet the fractal properties of invention suggest that limitless variations fall within the scope of most patent claims, frustrating any analysis based on a percentage.³⁸⁶ Unless, that is, most or all of those countless variations are based on differences so minor that persons of ordinary

³⁸⁰ PETROSKI, *supra* note 164, at 22.

³⁸¹ See 501 F.3d at 1277–78, 1285 (discussing electronic and mechanical sensors).

³⁸² *Id.* at 1285.

³⁸³ *Id.* at 1277–78.

³⁸⁴ *Id.* at 1278.

³⁸⁵ See, e.g., *AK Steel*, 344 F.3d at 1244 (requiring "reasonable enablement" of the scope of the claimed range).

³⁸⁶ Jeffrey Lefstin has argued that "[a]ll patent claims are of infinite scope," Lefstin, *supra* note 2, at 1168, and that "every claim is in the end a genus claim." *Id.* at 1206 (citation omitted). He attributes this to the "ontological nature of patent claims" as signifiers of the characteristics shared by the "set of entities" that possess the enumerated claim elements. *Id.* at 1168. In fact, it is not only the characteristics of peripheral claims that produce that boundless variety; it arises also from the fractal qualities of invention. Lefstin concludes that "[d]ue to the infinite scope of patent claims, a patentee certainly need not, and in most instances cannot, enable every embodiment falling within the 'full scope' of the claims." *Id.* at 1175.

skill in the art could practice them without undue experimentation. Although there might be inventions that simple and that devoid of the potential for non-obvious improvement, they must be rare. As previously discussed, even the paper clip has been the basis for continued innovation, including patentable innovation.³⁸⁷

It may be helpful to return to the image of invention as a continuously branching, ever-expanding Koch island.³⁸⁸ The claim in *Automotive Technologies* defines a portion of that island, populated by side-impact crash sensors including the elements set forth in the claim—a housing, a mounting assembly, a moveable mass within the housing, and a mechanism to detect the motion of the mass when subject to the forces of a collision.³⁸⁹ The last element, as interpreted by the court, includes mechanical and electronic sensors,³⁹⁰ so we might consider each a major branch of the claimed peninsula. Each of those branches may be subdivided. The mechanical branch may be subdivided into inertially damped sensors, spring-mass sensors, viscously damped sensors, and whatever other variations are possible. The inertially damped subdivision could be divided further into branches for flapper designs, as disclosed in the patent, and, presumably, a host of alternative designs. Returning to the electronic sensor branch, it could be subdivided into branches that employ optics, resistance change, capacitance change, magnetic reluctance change, and other variants not discussed in the patent, including radar, sonar, and laser interferometry. The subdivisions go on and on. The patentee cannot teach or even contemplate all of the embodiments on the perimeter, yet the patentee must supply the disclosure expected in exchange for exclusive rights.

What the Federal Circuit seems to expect is that no *major* branches be devoid of any enabled embodiments. If the disclosure does not enable one to build, without undue experimentation, an electronic crash sensor based on laser interferometry, the enabling disclosure may still be “reasonably” complete. But failure to enable *any* electronic sensor is an omission of the necessary quid pro quo, as is the failure to enable

³⁸⁷ See *supra* notes 162–180 and accompanying text. Perhaps one could argue that variations significant enough to be patented do not have to be enabled because those could not be enabled without further acts of invention. But it is precisely those variations that must be disclosed, because in these instances one cannot resort to the “gap-filling” of routine experimentation and the knowledge already possessed by those skilled in the art. See *Sitrick*, 516 F.3d at 999 (requiring that a patentee disclose enough information to enable someone skilled in the art to make or use it without undue experimentation).

³⁸⁸ See *supra* notes 6–8, 130–133 and accompanying text.

³⁸⁹ See 501 F.3d at 1277 (recounting the elements of the claim).

³⁹⁰ *Id.* at 1278–79.

any jacketless fluid injector. The question, then, is how we can distinguish a major branch of the claimed invention from a minor one. If we began the breakdown of the crash sensor invention with embodiments that use laser interferometry and embodiments that do not, then the failure to enable any of the former could be invalidating.

So far the Federal Circuit has relied on the patentee's characterization of the invention. In *AK Steel*, the specification suggested a fundamental distinction between Type 1 and Type 2 aluminum.³⁹¹ Type 1 aluminum was said to be unsuitable, and the claims of the patent initially avoided it.³⁹² Hence the alteration of the claims to include Type 1 aluminum looks like a major expansion of the territory subject to the claim. Similarly, in *Liebel-Flarsheim* the patent specification discouraged the omission of pressure jackets as impractical, and the claims, initially, were limited accordingly.³⁹³ This, and the failure of the inventors to devise their own jacketless injector, suggests a basic dichotomy between jacketed and unjacketed designs. *Automotive Technologies* is another matter. Here the specification did not teach away from electronic sensors, but tried to embrace them.³⁹⁴ Yet the patentee called attention to the distinction by separately illustrating an electronic sensor, and by leaving out so much detail that this portion of the disclosure stands in sharp contrast to the rest.³⁹⁵ The electronic sensor seems important to the inventors but beyond their grasp.³⁹⁶

One wonders what the court would have done if the patent had made no reference to an electronic sensor at all. Is it self-evident that an electronic sensor is a "distinctly different" embodiment that must be enabled?³⁹⁷ Even if an electronic sensor is an inherently superior alternative to a mechanical sensor, the same is true of any number of variants that cannot be enabled because they have not yet been invented. A basic tenet of patent law is that a product innovative enough to receive its own patent may still infringe another, if the new product is merely a

³⁹¹ 344 F.3d at 1236–37.

³⁹² *Id.*

³⁹³ 481 F.3d at 1374, 1379.

³⁹⁴ 501 F.3d at 1277–78 (noting that the district court agreed with the patentee that the claim could cover both mechanical and electronic sensors).

³⁹⁵ *Id.* at 1284.

³⁹⁶ *See id.* at 1283–85 (noting that the patentee described the use of an electronic sensor as a "breakthrough," but did not provide enough details of this new technology to allow someone skilled in the art to make or use it).

³⁹⁷ *See id.* at 1285 (describing electronic sensors as "distinctly different" from mechanical ones and requiring that they be separately enabled).

(non-obvious) species of a broadly claimed genus.³⁹⁸ That basic tenet would mean nothing if the genus patent were always invalid for failing to enable the species. Suppose the *Liebel-Flarsheim* patent included pressure jackets in the illustrated embodiments, but never referred to them in the claims or discussed them further in the specification. Suppose also that the inventors had never tried to develop a jacketless injector themselves. The omission of a pressure jacket in the accused product would have no bearing on infringement, however great an advancement it might represent, because it would not be an element of the claim.³⁹⁹ And it is far from certain that enablement would be an issue, any more than it would be an issue if the accused infringers happened to manufacture their syringe from an advanced material of their own devising.

If one adheres to the bargain model of patent law, the breadth of the enabling disclosure should match the breadth of the claim. Otherwise, the patentee receives more than bargained for. The problem will be applying that principle when the patentee did not clearly indicate, and failed to enable, a “major branch” of the claimed invention. A major branch should be one from which many subbranches depend. But the fractal properties of invention complicate such distinctions. If the network of variations is self-similar, then there is no scale for distinguishing a major branch from a minor one.⁴⁰⁰ Every branch can be the root of subbranches without limit, some that are accessible through routine experimentation, and many more that are not. Hence, the enabling disclosure of every patent is, from a certain perspective, infinitely lacking.

3. Variations Beyond “the Invention”

The “best mode” inquiry, which is beset by similar difficulties, suggests a slightly different approach. As a part of the patent bargain, the specification must disclose the best mode of practicing the claimed in-

³⁹⁸ See *Siemens Med. Solutions USA, Inc. v. Saint-Gobain Ceramics & Plastics, Inc.*, 637 F.3d 1269, 1278–83 (Fed. Cir. 2011) (explaining how a separately patented product may be held to infringe another); *Atlas Powder Co. v. E.I. du Pont de Nemours & Co.*, 750 F.2d 1569, 1580–81 (Fed. Cir. 1984) (explaining that the holder of a specific patent may not practice his or her own invention without a license from the holder of a broader patent that encompasses it (quoting *Herman v. Youngstown Car Mfg. Co.*, 191 F. 579, 584–85 (6th Cir. 1911))).

³⁹⁹ See DURHAM, *supra* note 282, at 150 (stating that “infringement is not avoided by adding things that are not described in the claim,” or by incorporating improvements to the product, provided that the infringing product contains “all elements” of the claim).

⁴⁰⁰ See *supra* notes 91–100, 203–209 and accompanying text.

vention known to the inventor.⁴⁰¹ If, before the filing date, the inventor designed a product embodying the invention, but omitted some information about that product from the application, a potential best mode violation has occurred.⁴⁰² Yet a patent application cannot, realistically, disclose *everything* about any product, including everything the inventor considered “best.” The best mode inquiry must be kept within bounds by treating only some product choices as “modes of practicing the invention.”

In 1991, in *Wahl Instruments, Inc. v. Acvious, Inc.*, the Federal Circuit discussed the dilemma of a patent applicant who had already developed a product.⁴⁰³ The invention concerned an immersible egg-timer with a layer of temperature-sensitive color-changing dye.⁴⁰⁴ The detail that the patentee failed to disclose was the use of a manufacturing technique known as “embedment molding.”⁴⁰⁵ The court determined that embedment molding was “no more than a routine manufacturing choice,” well-known in the art and chosen only because of cost.⁴⁰⁶ Although the inventor had thought embedment molding “best” for his product, it was not a choice that had to be disclosed in the patent:

Any process of manufacture requires the selection of specific steps and materials over others. The best mode does not necessarily cover each of these selections. To so hold would turn a patent specification into a detailed production schedule, which is not its function. Moreover, a requirement for routine details to be disclosed because they were selected as the “best” for manufacturing or fabrication would lay a trap for patentees whenever a device has been made prior to filing for the

⁴⁰¹ See 35 U.S.C. § 112, para. 1 (2006), amended by Leahy-Smith America Invents Act, Pub. L. No. 112-29, § 4(c), (e), 125 Stat. 284, 296–97 (2011) (effective Sept. 16, 2012) (stating the specification “shall set forth the best mode contemplated by the inventor of carrying out [an] invention”); *Amgen, Inc. v. Chugai Pharm. Co.*, 927 F.2d 1200, 1209–10 (Fed. Cir. 1991) (describing the best-mode disclosure as part of the “*quid pro quo* of the patent grant”).

⁴⁰² See *Bayer AG v. Schein Pharm. Inc.*, 301 F.3d 1306, 1316 (Fed. Cir. 2002) (noting that courts have held the best-mode requirement violated by the “failure to disclose a preferred embodiment, or else failure to disclose a preference that materially affected making or using the invention”). Although the recent patent reform legislation removed best mode non-disclosure as grounds for holding a patent invalid, 35 U.S.C. § 112 still demands that the inventor set forth the best mode. Leahy-Smith America Invents Act, Pub. L. No. 112-29, § 15(a), 125 Stat. 284, 328 (2011) (effective Sept. 16, 2011).

⁴⁰³ 950 F.2d 1575, 1577–78 (Fed. Cir. 1991).

⁴⁰⁴ *Id.*

⁴⁰⁵ *Id.* at 1578.

⁴⁰⁶ *Id.* at 1580–81.

patent. The inventor would merely have to be interrogated with increasing specificity as to steps or material selected as “best” to make the device. A fortiori, he could hardly say the choice is not what he thought was “best” in some way. Thus, at the point he would testify respecting a step or material or source or detail which is not in the patent, a failure to disclose the best mode would, *ipso facto*, be established.⁴⁰⁷

An inventor who produces a commercial embodiment ventures down the fractal path, making a series of choices of increasing detail. Some choices are made for “non-‘best-mode’ reason[s],” such as the availability of materials or a prior relationship with a supplier.⁴⁰⁸ They may have nothing to do with making the invention work better. Embedment molding was such a choice because it “did not affect and was not thought to affect how [the] invention worked.”⁴⁰⁹ Consequently, it “clearly fell outside the scope of the invention.”⁴¹⁰

Enablement is a question of the *range* of disclosure, so what makes the invention work better is a less useful metric for what is “outside the scope of the invention.” On the other hand, a variation of a variation of a variation may seem, at some point, too remote from the claimed invention to be a part of it any longer. Suppose that someone used a newly discovered, scratch-resistant plastic to make a nectar-mixing apparatus of the sort claimed in the Klein application. Although Klein did not enable a device made from that material, he might argue that his invention was about mixing nectar, not avoiding scratches. This non-enabled variation may be so far from Klein’s contribution to the art that it is no longer relevant to his invention.

Unfortunately, in the enablement context there is no easy way to distinguish a variation that is part of the invention from one that is not. Suppose that the inventors in *Liebel-Flarsheim* had recommended shatterproof plastic rather than breakable glass for their syringe, but later a competitor developed a tough variety of glass that could be substituted. Would failure to enable glass syringes invalidate the patent? The patentee might argue that a new variety of glass is an entirely separate invention. On the other hand, finding a way to dispense with a pressure jacket might be thought a separate invention too. These remote varia-

⁴⁰⁷ *Id.* at 1581.

⁴⁰⁸ *Id.*

⁴⁰⁹ *Wahl Instruments*, 950 F.2d at 1581.

⁴¹⁰ *Id.*

tions, like the major branches of a claimed invention, are not self-defining.

When the patentees themselves do not signal the presence of a fundamental and non-enabled variation (and patentees, at this point, should be careful about what they volunteer), courts may begin by focusing on the problem solved by the claimed invention. The Klein application is about mixing nectar, so the failure to enable a device that resists scratches does not seem unreasonable in relation to what Klein claims as his invention. The fractal nature of invention, however, suggests that there are, inevitably, countless non-enabled variations of Klein's invention that are very much about mixing nectar. How courts will deal with those situations as they move forward is difficult to predict.

4. Backtracking by Omission

One approach may be to distinguish between non-enabled additions and omissions. Imagine an open-ended claim to the combination A, B, C. The combination could be diagrammed as a portion of a fractal network, the first branch of which divides A from $\neg A$ (meaning *not* A). From the A branch extend two subbranches: A, B (A combined with B) and A, $\neg B$ (A combined with anything but B). From A, B extend two further branches: A, B, C, and A, B, $\neg C$. Because adding to the claimed combination does not avoid infringement, the claim A, B, C reads on every variant A, B, C, D, including some varieties of D that were not enabled.⁴¹¹ That type of non-enablement is unavoidable. Suppose, however, that *all* of the embodiments enabled by the patent applicant include elements A, B, and C. No enabled embodiment is to be found on the A, B, $\neg C$ portion of the fractal, either through the applicant's disclosure or through what a person of ordinary skill could achieve without undue experimentation. If the applicant claimed A, B (encompassing A, B, C *and* A, B, $\neg C$), one could conclude that the scope of the enablement did not match the scope of the claim.

Claiming A, B in this instance would represent the applicant backtracking from the enabled invention—moving inland from the coastline, if we continue the Koch island metaphor—by omitting something (namely, C) from the claimed invention. Backtracking of this sort is a normal part of technological development. Klein, for example, may well have begun with the moveable-divider variant of his nectar-mixing device, only to realize that a device without such a divider could be use-

⁴¹¹ See DURHAM, *supra* note 282, at 150.

ful too. But Klein enabled variants without moveable dividers, so there is no reason he should not claim them. Our hypothetical inventor, however, did not enable any combination without C, so a court may be justified in rejecting the claim to A, B alone.⁴¹²

Judge Lourie would argue that this is exactly the situation presented in the three cases previously discussed. The claim in *AK Steel* omitted the Type 2 aluminum essential to the applicant's process.⁴¹³ The claim in *Liebel-Flarsheim* omitted the pressure jacket that all of the inventors' syringes possessed.⁴¹⁴ The claim in *Automotive Technologies* omitted the mechanical sensor.⁴¹⁵ In *Arlington* as well, the inventor omitted a limitation to the split-ring adapter that was the only variant contemplated or disclosed.⁴¹⁶ In each case, the inventor laid claim to a branch of the fractal devoid of any enabled embodiment, and therefore beyond the scope of what had really been invented.

But there are some difficulties with this analysis. Suppose our hypothetical inventor did enable one embodiment on the A, B, \neg C branch (a variant we will call A, B, X) but failed to enable another (which we will call A, B, Y). Having enabled *something* on both the A, B, C and the A, B, \neg C branches, we might conclude that the inventor is entitled to the A, B claim that encompasses both. But there is still a subbranch of the fractal (A, B, Y and all of its subsidiary variants) for which there are no enabled embodiments. Logically, this inventor should have *two* specific claims (A, B, C and A, B, X), rather than a general claim to A, B. By omitting C *or* X as a claim limitation, the inventor has generalized the invention in a manner that the enabling disclosure cannot support. The problem with this conclusion is that it would invalidate most patent claims. Because of the endless branching of invention, most patent claims encompass a branch, such as A, B, Y,

⁴¹² See *Arlington*, 632 F.3d at 1257–58 (Lourie, J., concurring in part and dissenting in part) (stating that claims should not cover embodiments that were not invented by the patentees and described in their application).

⁴¹³ See 344 F.3d at 1237–38 (reproducing the claims, which could cover Type 1 or Type 2 aluminum).

⁴¹⁴ See 481 F.3d at 1373–74 (recounting an exemplary claim and stating that the claims did not explicitly require the presence of pressure jackets).

⁴¹⁵ See 501 F.3d at 1277 (reproducing Claim 1 that does not indicate that the sensor must be mechanical).

⁴¹⁶ See 632 F.3d at 1251–52 (reproducing Claim 1 that does not indicate that the adapter must have a split ring).

that is not specifically contemplated, disclosed, or enabled in any embodiment.⁴¹⁷

Suppose, for example, that the claims in *Liebel-Flarshiem* had been limited to injectors with pressure jackets, and that the single design illustrated in the specification included such a jacket, which we will call jacket X. Let us further suppose that pressure jackets are not the “perfected artifact” to which Petroski refers,⁴¹⁸ so another inventor eventually develops an alternative jacket Y. The inventors were correct to claim only injectors with pressure jackets, but if they failed to specify model X jackets, their claims are still invalid. The inventors could be safe only by adding claim limitation upon claim limitation until there is no embodiment within the scope of the claim that is non-enabled—an objective that could rarely be achieved. Although it is a valid point that backtracking from the enabled embodiments can lead to unsupported claims, a rule that can be rigorously applied seems impossible. We still must distinguish, somehow, between major and minor omissions.

E. *Describing the Fractal Invention*

A patent specification must provide, in addition to an enabling disclosure, a “written description” of the invention.⁴¹⁹ The description requirement ensures a match between the claimed invention and the invention disclosed in the patent application.⁴²⁰ Although it may be most useful when claims have changed during prosecution, the description requirement has been used, like the enablement requirement, to invalidate genus claims that are inadequately supported by the species detailed in the patent specification.⁴²¹ The standard is whether the specification “reasonably conveys to those skilled in the art that the inventor had possession of the claimed subject matter as of the filing date.”⁴²² The fractal qualities of invention complicate application of the

⁴¹⁷ See Lefstin, *supra* note 2, at 1175 (“Due to the infinite scope of patent claims, a patentee certainly need not, and in most instances cannot, enable every embodiment falling within the ‘full scope’ of the claims.”).

⁴¹⁸ See PETROSKI, *supra* note 164, at 22 (asserting that there can be no “‘perfected’ artifact,” as “the form of made things is always subject to change”).

⁴¹⁹ 35 U.S.C. § 112, para. 1 (2006), amended by Leahy-Smith America Invents Act, Pub. L. No. 112-29, § 4(c), (e), 125 Stat. 284, 296–97 (2011) (effective Sept. 16, 2012).

⁴²⁰ DURHAM, *supra* note 282, at 91.

⁴²¹ See, e.g., *In re Curtis*, 354 F.3d 1347, 1352–53 (Fed. Cir. 2004) (holding that the written description of one species failed to support a genus claim to friction-enhancing coatings for dental floss).

⁴²² *Eli Lilly & Co.*, 598 F.3d at 1351 (citations omitted).

description requirement in the same way they complicate application of the enablement requirement.

Boston Scientific Corp. v. Johnson & Johnson, a case decided by the Federal Circuit in 2011, provides a recent illustration.⁴²³ The patents concerned drug-eluting arterial stents that prevent blockages from returning after a balloon angioplasty—an effect known as restenosis.⁴²⁴ The claims covered the use of the known drug rapamycin or analogs of rapamycin.⁴²⁵ The patent specifications disclosed no example of a rapamycin analog, and admitted that research had not yet revealed the precise mechanism that made rapamycin effective.⁴²⁶

A written description of a genus—like the genus of rapamycin analogs—“requires the disclosure of either a representative number of species falling within the scope of the genus or structural features common to the members of the genus so that one of skill in the art can ‘visualize or recognize’ the members of the genus.”⁴²⁷ The universe of compounds structurally similar to rapamycin is “potentially limitless,”⁴²⁸ and even minor changes might render such chemicals ineffective substitutes.⁴²⁹ Although the number of species that must be disclosed “changes with each invention” and “changes with progress in a field,”⁴³⁰ in the absence of any example of a rapamycin analog, or any discussion of their attributes other than the ability to substitute for rapamycin, the disclosures here could not demonstrate possession of the claimed genus.⁴³¹ The claims covered “tens of thousands of possible . . . analogs,” and the specification provided “no guidance at all . . . as to how to properly identify or choose” those chemicals that could substitute for rapamycin.⁴³² In sum, “[t]he patent laws do not reward an inventor’s invitation to other researchers to discover which of the thousands of . . . analogs of rapamycin could conceivably work in a drug-eluting stent.”⁴³³

⁴²³ See 647 F.3d 1353, 1368–69 (Fed. Cir. 2011) (holding a claim to the use of analogs of rapamycin invalid under the written description requirement when no such analogs were disclosed).

⁴²⁴ *Id.* at 1356.

⁴²⁵ *Id.* at 1357.

⁴²⁶ *Id.* at 1358–59.

⁴²⁷ *Id.* at 1363 (quoting *Ariad*, 598 F.3d at 1350).

⁴²⁸ *Id.* at 1364.

⁴²⁹ See *Bos. Scientific*, 647 F.3d at 1364 (noting that minor structural differences in such analogs “may have significant and unpredictable effects on functionality”).

⁴³⁰ *Id.* at 1363 (quoting *Ariad*, 598 F.3d at 1351).

⁴³¹ *Id.* at 1369.

⁴³² *Id.* at 1365.

⁴³³ *Id.* at 1367.

The inventors in *Boston Scientific* knew that one chemical, rapamycin, prevented restenosis, and they foresaw that structurally similar chemicals, yet to be identified, would do the same.⁴³⁴ In order to have a patent that would not be easily avoided, they claimed the genus of rapamycin analogs.⁴³⁵ If arterial stents were a fractal island, we could imagine its structure as follows: drug eluting stents are one peninsula; from that depends a sub-peninsula of stents that use chemicals structurally similar to rapamycin; and a portion of that sub-peninsula covers rapamycin itself. Like many inventors, the inventors in *Boston Scientific* tried to generalize what they had discovered—taking a step back, just as the inventors in *Liebel-Flarsheim* stepped back from pressure jackets and the inventors in *Automotive Technologies* stepped back from mechanical sensors. The question is whether such stepping back, and the consequent broadening of the patent, can be justified. Did the inventors “possess” the broader invention?

As Judge Arthur Gajarsa points out in his concurring opinion to *Boston Scientific*, this could have been addressed through the enablement requirement.⁴³⁶ The inventors identified only one chemical (rapamycin itself) in the genus of chemicals that are structurally similar to rapamycin and effective to prevent restenosis.⁴³⁷ In light of the unpredictability of the art, discovery of other members of the genus would require undue experimentation.⁴³⁸ The patent’s disclosures, accordingly, did not provide reasonable enablement of the scope of the claimed range.⁴³⁹ Approaching the same issue through the description requirement only changes things slightly. The inventors “possessed” the genus in the sense that they could imagine it, but not in the sense that they could identify whether a particular chemical fell within the genus.⁴⁴⁰ If the inventors had been able to provide a few more examples of chemicals like rapamycin, then the question would be whether those

⁴³⁴ See *id.* at 1364 (finding that the specification demonstrated that the patentee was “in possession” of rapamycin but not its analogs).

⁴³⁵ See *Bos. Scientific*, 647 F.3d at 1357 (stating that the claims covered rapamycin and its analogs).

⁴³⁶ *Id.* at 1369 (Gajarsa, J., concurring).

⁴³⁷ See *id.* at 1369–70 (finding that none of the analogs were shown to be effective).

⁴³⁸ *Id.*

⁴³⁹ *Id.* at 1370.

⁴⁴⁰ See *id.* at 1363 (majority opinion) (agreeing with the defendant that nothing in the patents show that the “inventors possessed drug-eluting stents employing the broad genus of . . . analogs,” as they did not give any examples or identifying features of such analogs).

examples constitute a “representative number of species.”⁴⁴¹ If the fractal here is one that branches endlessly, then we have the familiar problem of determining how many species of the genus are enough to be “representative.”

The description requirement often arises in cases involving the chemical or biological arts, which may differ from the mechanical arts that we have so far discussed.⁴⁴² The structural elements necessary to produce a chemical effect may be so specific that, once those structures are identified, everything else falls into place.⁴⁴³ With further research, the inventors in *Boston Scientific* might have been able to describe, by their structural attributes, every molecule that is an analog of rapamycin. Or they might have revealed those structural attributes through examples. Such completeness cannot be expected in a field like crash sensors, in which the alternatives are probably inexhaustible. On the other hand, even in the chemical arts one can step back far enough that no description, other than one based on function alone, can include all of the subject matter claimed, or demonstrate “possession” in any but the most abstract sense. For example, the inventors in *Boston Scientific* could have claimed all drugs that prevent restenosis, no matter how they work. The issue remains this: how much of the fractal island can an inventor claim, based on the discovery, enablement, and “possession” of just a portion of that endlessly branching and ever-evolving structure? If the fractal model is an accurate one, no answer is likely to prove satisfying.

F. Abstract Ideas

The hypothetical claim that embraces *all* means of preventing restenosis recalls another area of patent law in which the fractal nature of invention plays a role—the long-standing prohibition on patenting “abstract ideas.”⁴⁴⁴ Courts have used the abstract ideas exception to de-

⁴⁴¹ See *Bos. Scientific*, 647 F.3d at 1363 (stating that a genus may be adequately described by providing a representative number of examples or identifying structural features of members of the genus).

⁴⁴² See *MERGES ET AL.*, *supra* note 294, at 201–03 (discussing several cases in which the written description requirement was applied to biotechnology).

⁴⁴³ See *Bos. Scientific*, 647 F.3d at 1370 (Gajarsa, J., concurring) (suggesting that “[o]nce rapamycin’s structure was known, scientists could hypothesize that useful analogs could potentially be created by changing parts of that molecule”).

⁴⁴⁴ See *Bilski*, 130 S. Ct. at 3225 (noting that abstract ideas have long been held not patentable).

ny patents to intangible or non-technological inventions,⁴⁴⁵ and also to address claims broader than the patentee's contribution to the art.⁴⁴⁶ Perhaps the most famous example of the latter is the venerable U.S. Supreme Court case from 1854, *O'Reilly v. Morse*, which invalidated one claim of Samuel Morse's patent on the telegraph.⁴⁴⁷ Claim 8 of Morse's patent extended to any use of electromagnetism to convey printed messages.⁴⁴⁸ The court acknowledged the value of Morse's telegraph and his entitlement to a patent,⁴⁴⁹ but decided that Claim 8 went too far beyond the means of communication that Morse had discovered.

If this claim can be maintained, it matters not by what process or machinery the result is accomplished. For aught that we now know some future inventor, in the onward march of science, may discover a mode of writing or printing at a distance by means of the electric or galvanic current, without using any part of the process or combination set forth in the plaintiff's specification. His invention may be less complicated—less liable to get out of order—less expensive in construction, and in its operation. But yet if it is covered by this patent the in-

⁴⁴⁵ See Alan L. Durham, *The Paradox of "Abstract Ideas,"* 2011 UTAH L. REV. (forthcoming 2012); see also Christina Bohannon & Herbert Hovenkamp, *IP and Antitrust: Reformation and Harm*, 51 B.C. L. REV. 905, 951–64 (2010) (discussing early and recent examples of cases in which inventions that lacked "tactile engagement" were denied patents under the abstract ideas doctrine).

⁴⁴⁶ See Dan L. Burk & Mark A. Lemley, *Policy Levers in Patent Law*, 89 VA. L. REV. 1575, 1642 (2003) ("The rule against patenting abstract ideas, while couched in terms of patentable subject matter, is really a judicial effort to restrict the permissible scope of patents and to channel patent protection towards finished products.").

⁴⁴⁷ 56 U.S. (15 How.) 62, 63 (1853).

⁴⁴⁸ *Id.* at 112. Claim 8 of Morse's patent stated:

I do not propose to limit myself to the specific machinery or parts of machinery described in the foregoing specification and claims; the essence of my invention being the use of the motive power of the electric or galvanic current, which I call electro-magnetism, however developed for marking or printing intelligible characters, signs, or letters, at any distances, being a new application of that power of which I claim to be the first inventor or discoverer.

Id.

⁴⁴⁹ *Id.* at 117. The court noted:

[I]t is the high praise of Professor Morse, that he has been able, by a new combination of known powers, of which electro-magnetism is one, to discover a method by which intelligible marks or signs may be printed at a distance. And for the method or process thus discovered, he is entitled to a patent.

Id.

ventor could not use it, nor the public have the benefit of it without the permission of this patentee.⁴⁵⁰

According to *Morse*, a patentee who exploits natural forces, like electromagnetism, for practical ends must “specif[y] the means he uses” and claim only those.⁴⁵¹ Yet there are other cases, of similar vintage, cautioning against limiting inventors too stringently to a particular mechanism.⁴⁵² The *Morse* opinion itself refers to *Neilson et al. v. Harford*, an English case from 1841, which upheld the validity of a patent for a furnace design.⁴⁵³ Neilson improved the efficiency of combustion by preheating the air in a separate vessel.⁴⁵⁴ Even though his patent did not specify the form of the vessel or the manner of heating it, the English court held Neilson’s patent valid.⁴⁵⁵ The Supreme Court in *Morse* approved of that result, because Neilson’s invention did not depend on the characteristics of the vessel.⁴⁵⁶ Any heated vessel would produce the desired effect “in greater or lesser degree.”⁴⁵⁷ In contrast, success in transmitting messages by electromagnetism depended on the apparatus employed.⁴⁵⁸

All patent claims are, by their nature, abstract. A mousetrap claim does not describe a particular mousetrap, but the class of all mousetraps possessing the enumerated characteristics. Abstraction is also an aspect of invention. Velcro could not have been developed if de Mestral had not abstracted from the particulars of the cocklebur the inventive concept of hook-and-loop fasteners. Consequently, the simple admonition that “abstract ideas” cannot be patented leaves much to be desired. Abstractness is, for all patent claims, a matter of degree. As I have argued elsewhere, the best way to measure whether a claim is *too* abstract is in comparison to the teachings of the patent disclosure, as one does in the context of the enablement and description requirements.⁴⁵⁹ Indeed, although *Morse* has been called the origin of the abstract ideas

⁴⁵⁰ *Id.* at 113.

⁴⁵¹ *Id.* at 119.

⁴⁵² See, e.g., *Neilson et al. v. Harford*, (1841) 151 Eng. Rep. 1266 (Exch. of Pleas.) 1273 (holding a patent valid when the patentee claimed a “machine embodying a principle,” not merely the principle itself).

⁴⁵³ *O’Reilly*, 56 U.S. at 114, 116 (citing *Neilson et al.*, 151 Eng. Rep. at 1266).

⁴⁵⁴ *Id.* at 114–15.

⁴⁵⁵ *Id.* at 115–16.

⁴⁵⁶ *Id.* at 115–17.

⁴⁵⁷ *Id.* at 116.

⁴⁵⁸ *Id.* at 117.

⁴⁵⁹ Durham, *supra* note 445.

exception to patentable subject matter,⁴⁶⁰ the Federal Circuit has observed that it might be interpreted as a written description case.⁴⁶¹ As a tool to confront overbreadth, the abstract ideas prohibition is as unnecessary as it is misleading.

So long as the patent system demands a quid pro quo of disclosure in exchange for exclusive rights, patents that claim more of the fractal island than the inventor's teachings can justify should be rejected. Perhaps a claim like Morse's Claim 8 is in a special category because no amount of disclosure could *ever* match the scope of the exclusive rights that he sought. When applying the abstract ideas prohibition, however, courts should bear in mind the limitations that face all patent applicants. A claim "abstracts" certain aspects of the invention (claim elements A, B, C) because that is how applicants describe the portion of the fractal to which they assert exclusive rights—just as one might describe a portion of a Koch island by reference to its roots, rather than its infinitely complex perimeter. In most cases, the patent will not, and cannot, disclose all variations within the scope of the claims. There are too many branches for that to be possible. All claims represent abstract ideas. Therefore, the best tool for ensuring an adequate quid pro quo is not the yes-or-no inquiry of patentable subject matter, but the more nuanced analysis of section 112's enablement and written description requirements.

CONCLUSION

Patent law is rife with difficult questions: What is "the invention"? How broadly may it be claimed? How much disclosure is needed to enable it, or demonstrate that the inventor "possessed" it? When is an idea too "abstract" to be patented? Although recognizing the fractal nature of invention does not supply easy answers to these questions, it suggests why the answers are so elusive. Technological progress is the product of continuous growth and limitless complexity. In some respects, trying to fix an invention in a verbal summary and a teaching disclosure is as futile as trying to draw a portion of a Koch island; in either case, one can only sketch the outlines and appeal to the imagination. Fortunately, patent law is a practical discipline, not a mathematical one. Perfection is unnecessary, so long as the result promotes the progress of the useful arts as the framers of the Constitution intended. If courts recognize the

⁴⁶⁰ See Burk & Lemley, *supra* note 446, at 1642 (calling *Morse* the origin of the abstract ideas exclusion).

⁴⁶¹ *Ariad*, 598 F.3d at 1346 n.4.

fractal properties of invention, the compromises they reach will at least be better informed, more honest, and perhaps more effective in serving their ultimate goal.

