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Historic Perspectives on Law & Science

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¶1 Law has had a long and troubled relationship with science. The misuse of science within the legal realm, as well as our failed attempts to make law more scientific, are well documented.¹ The cause of these problems, however, is less clear.

¶2 I would like to suggest that the unsatisfying relationship of law and science can be attributed, at least in part, to law's inadequate understanding of what constitutes science and law's inflated view of the potential benefits of science for law. It is our failure to understand what science knows about its own enterprise, as well as our fervent hope that law could be something other than it is, that leads us astray.

¶3 In highly simplified form, what we think of as science today began its history deeply entwined with philosophy and theology. During the Scientific Revolution, science separated from other types of intellectual endeavor, although the lines of demarcation were never solid. In the mid-twentieth century, philosophers challenged the notion that science could be so neatly discrete, although they were unable to settle on a coherent definition. An uneasy truce developed in which science is, at best, defined as a cluster of concepts, albeit ones that do not work individually or even as a whole. For my purposes, the important point is the following: those things that make science what it is are a far cry from law's vision of science. Such distortions in law's understanding of the nature of science magnify the problems created when law tries to import structures from science to solve its problems.

¶4 Some would argue that problems at the intersection of law and science flow from the changing nature of science. Law is too slow to adapt to the changing information available through the advancements of science, particularly for issues that are dependent on the Supreme Court revisiting

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¹ See, e.g., ROBIN FELDMAN, *THE ROLE OF SCIENCE IN LAW* (forthcoming Oxford University Press 2009); DAVID FAIGMAN, *LABORATORY OF JUSTICE: THE SUPREME COURT'S 200-YEAR STRUGGLE TO INTEGRATE SCIENCE AND THE LAW* (2004); DAVID FAIGMAN, *LEGAL ALCHEMY: THE USE AND ABUSE OF SCIENCE IN THE LAW* (1999); Ronald Dworkin, *Social Sciences and Constitutional Right—the Consequences of Uncertainty*, 6 J.L. & EDUC. 3 (1977); Steven Goldberg, *The Reluctant Embrace: Law and Science in America*, 75 GEO. L.J. 1341 (1987); Dean Hashimoto, *Science as Mythology in Constitutional Law*, 76 OR. L. REV. 111 (1997); Oliver Wendell Holmes, *Law in Science and Science in Law*, 12 HARV. L. REV. 443 (1899); Richard Lempert, "Between Cup and Lip": *Social Science Influences on Law and Policy*, 10 LAW & POL'Y 167 (1988); Karl N. Llewellyn, *The Theory of Legal "Science"*, 20 N.C. L. REV. 1 (1942); Howard T. Markey, *Jurisprudence or "Juris-science"?*, 25 WM. & MARY L. REV. 525 (1984); Roscoe Pound, *Law and the Science of Law in Recent Theories*, 43 YALE L.J. 525 (1934); J. Alexander Tanford, *The Limits of a Scientific Jurisprudence: The Supreme Court and Psychology*, 66 IND. L.J. 137 (1990-1991); Charles R. Tremper, *Sanguinity and Disillusionment Where Law Meets Social Science*, 11 LAW & HUM. BEHAV. 267 (1987); John Veilleux, Note, *The Scientific Model in Law*, 75 GEO. L.J. 1967 (1987).

those issues. Delay in the legal system is certainly a problem when law and science interact. In my view, however, the deepest problems flow not from the changing nature of science but from the changing nature of law.

¶5 Law is by its nature evolutionary and adaptive. There are no ultimate doctrinal structures in law because there are no ultimate questions. Those wishing to escape the constraints of any doctrinal structure will seek out the open spaces, the interstices among those things that have been decided. Cases will naturally emerge within the spaces of whatever structure exists, rendering that structure insufficient for resolving the new question.

¶6 When we borrow structures from science, the adaptive process breaks down, and it does so for several reasons. The most obvious is that we do not understand the science we are importing or applying. As a result, we do not allow law to evolve in a very effective or nuanced fashion. More important, however, is our tendency to imagine that science is clear and certain. We forget that scientific lines and categories are themselves no more than constructs. They are ways of creating shared understandings within the scientific community. In a legal context, however, we easily lose sight of the artificiality and the assumptions that such constructs embody. We become fixated on scientific categorizations, as if lines drawn by science have some mysterious power that we can access by invoking them.² As a result, we fail to engage in the natural evolution and adaptation of the resulting doctrines. In short, when the legal system relies on science to craft its rules, those rules lack the flexibility and dexterity necessary for effective participation in the evolution of legal doctrine.

¶7 With this in mind, the article begins by describing law's vision of science as an enterprise that is reliable, sustainable, and true in some absolute sense. The article then contrasts that view with science's vision of its own enterprise as something much more limited. In particular, it describes the turmoil that developed during the twentieth century over the definition of science and the uneasy truce that has emerged. Finally, the article explores the nature of law and suggests that the constantly evolving nature of law makes science a bad fit for the way we try to use it in the development of legal doctrines.

I. LAW'S VISION OF SCIENCE

¶8 The notion of what constitutes science has perplexed philosophers across hundreds of years of human history—often in the context of trying to identify what is *not* science. In particular, the last half-century has witnessed nothing short of a revolution in thinking about what constitutes science. The upheaval has left philosophers and scientists without agreement on a coherent definition of science.

¶9 To illustrate the problems, let me offer two stories. In the first, a man is walking down a suburban street rubbing two sticks together. A passerby asks the man what he is doing, and the man replies that he is keeping elephants away. The passerby scoffs, "How in the world can rubbing sticks together keep elephants away?" The man replies: "Do you see any elephants?"

¶10 In the second story, imagine that a scientist living long before the invention of the microscope theorizes the existence of bugs smaller than lice that live in or on our bodies and make us sick.³ He designates these bugs "crobes" and develops health recommendations based on their existence, including that healthy people should avoid contact with the sick and that anyone coming in contact with the sick should wash their hands and their clothing. The recommendations lead to a reduction in the spread of disease. In looking at the two stories, how do we develop criteria to decide what constitutes science and what does not?

² Cf. Roscoe Pound, *Mechanical Jurisprudence*, 8 COLUM. L. REV. 605, 606 (1908) ("The effect of all system is apt to be petrification of the subject systematized. Perfection of scientific system and exposition tends to cut off individual initiative in the future, to stifle independent consideration of new problems and of new phases of old problems, and to impose the ideas of one generation upon another.").

³ This story is adapted from Grover Maxwell, *The Ontological Status of Theoretical Entities*, in *INTRODUCTORY READINGS IN THE PHILOSOPHY OF SCIENCE* 363, 363-66 (E.D. Klemke et al. eds., 1998).

- ¶11 Although the question of what constitutes science is devilishly complex, the inquiry for our purposes is somewhat simpler. The ultimate question is not so much what is science but rather, what does law *think* science is, and what are the gaps between that vision and our modern understanding of science.
- ¶12 Law’s definition of science is fairly uncluttered. It is nicely reflected in a contemporary court’s definition of science as “the process by which knowledge is systematized or classified through the use of observation, experimentation, or reasoning.”⁴ As one author explained very simply in a book concerning what lawyers need to know about science, “[s]cience is the best way to understand the way the world works. It has had enormous success in explaining physical, chemical and biological processes . . . though there remain great areas of ignorance.”⁵
- ¶13 Thus, law’s definition begins with the notion that society possesses knowledge, that is, things that are both knowable and true. Science then has the capacity to add to that knowledge and to organize it in a way that is manageable and can lead to future insights. Its methods of organization are grounded in objectivity, which generate confidence in the reliability of its results.
- ¶14 Implicit in the definition is the notion that science is cumulative and progressive. In other words, the body of knowledge that science offers continues to build on the knowledge that comes before, leading us to an increased understanding of the world around us. It calls to mind an image of scientists tinkering with old insights and adding new revelations. In the words of one author, “[s]cience . . . is progressive . . . approach[ing] closer and closer to understanding the nature of the world.”⁶
- ¶15 Also implicit in law’s definition of science is a veneration of things scientific and a separation from those things that are not science. Science is something of value, in which we can have confidence. As one legal author has noted, “[a]lthough [science’s] conclusions may be speculative, provisional, and subject to modification, science is ordinarily seen as set apart from all other social activities by virtue of its institutionalized procedures for overcoming particularity and context dependence and its capacity for generating claims of universal validity.”⁷ In other words, science and scientific methods help us get to information that is reliable, sustainable, and true in some absolute sense.
- ¶16 This definition of science probably feels comfortable and familiar to a legal audience. Nevertheless, it varies significantly from the view of science held within the world of science today.

II. THE ENTERPRISE VIEWS ITSELF

- ¶17 The bodies of thought that we think of as science today, did not separate from other types of thought until the Scientific Revolution in Europe in the 1500s and 1600s.⁸ At the opening of this period in Europe, the term “philosophy” was still used to describe both things that we would consider philosophy and things that we would consider science.⁹ Not only were science and philosophy intertwined, all intellectual inquiry was intertwined with and considered subordinate to the theology of the Christian Church.

⁴ *ITT Research Inst. v. United States*, 9 Cl. Ct. 13, 20 (1985).

⁵ See Lewis Wolpert, *What Lawyers Need to Know About Science*, in 1 *LAW AND SCIENCE: CURRENT LEGAL ISSUES*, 289, 289 (Helen Reece ed., 1998).

⁶ See *id.*; see also Jon Frauley, *Towards an Archaeological-Realist Foucauldian Analytics of Government*, 47 *BRIT. J. CRIMINOLOGY* 617, 618-21 (2007) (describing tenets of critical realism including that there is an objective truth and that science undergoes continual revision towards a better, although imperfect, understanding of it).

⁷ SHEILA JASANOFF, *SCIENCE AT THE BAR: LAW, SCIENCE, AND TECHNOLOGY IN AMERICA* 7 (1995).

⁸ For thorough and fascinating views of the history of science, see the two-volume set, GEORGE SARTON, *A HISTORY OF SCIENCE* (1952) as well as the two-volume set, A. WOLF, *A HISTORY OF SCIENCE, TECHNOLOGY, AND PHILOSOPHY IN THE 16TH & 17TH CENTURIES* (1935). For comprehensive sets of readings that introduce the field of philosophy of science, see *PHILOSOPHY OF SCIENCE: THE CENTRAL ISSUES* (Martin Curd & J.A. Cover eds., 1998); Maxwell, *supra* note 4; see also ALEX ROSENBERG, *PHILOSOPHY OF SCIENCE: A CONTEMPORARY INTRODUCTION* (2d ed. 2005).

⁹ See WOLF, *supra* note 8, at 1.

- ¶18 As Europe emerged from the mediaeval period, however, science began the slow process of pulling away, first from the hand of the church and then from philosophy's embrace. In the process, science established an identity for itself. This identity was centered on developing theories from observable facts and experimentation and distinguished from both the theological revelations of the Church and the more speculative and contemplative inquiries of philosophy.¹⁰
- ¶19 In most cases, the men of the scientific revolution were deeply religious and loyal sons of the church.¹¹ They operated under the assumption that the study of nature could only reveal the majesty of the divine. These profoundly religious thinkers, however, had to reconcile the insights of reason and observation with loyalty to the church.¹² Ideas like the Copernican view that the earth revolves around the sun directly conflicted with church dogma.¹³
- ¶20 Many scientific thinkers tried to find approaches that would artfully avoid the conflict altogether. These approaches sowed the seeds of the eventual separation of science from theology, as well as from other types of intellectual endeavor. For example, some carefully couched their explorations in instrumental terms, suggesting that it was simply useful to think about planetary movements in a particular fashion, regardless of whether there was any ultimate truth to the construction.¹⁴
- ¶21 The notion of usefulness is intrinsic to other views of science at this period of time. Science often is more like engineering or problem-solving. Understanding the movement of the stars helps ships navigate, for example. It is not necessary to look for the goodness or justice or morality of the movement to benefit from the information. Thus, some tried to define a narrow and limited space for the explorations of science, one that hopefully would not offend or conflict with the Church.
- ¶22 Others tried to avoid conflict by more explicitly delineating separate spheres for science and theology, ones that would implicitly limit the role of the Church. For example, the philosopher and astronomer Giordano Bruno suggested that the Bible should be followed for its philosophy rather than its astronomy.¹⁵ Thus, the teachings of both could comfortably co-exist. Galileo himself noted that the Church in the past had sanctioned allegorical interpretations of the Bible when its teachings appeared to conflict with scientific evidence.¹⁶
- ¶23 The Catholic Church initially did not object to these emerging theories of the universe. With Protestant reformers nipping at their heels, however, the Church eventually moved to suppress them, sometimes with great brutality.¹⁷ As one scholar noted in describing the fate of Bruno, "[h]is stated

¹⁰ See, e.g., RENÉ DESCARTES, DISCOURSE ON METHOD AND THE MEDITATIONS 21 (John Veitch trans., Prometheus Books 1989) (1637). For a general discussion of intellectual thought during this period, see STEPHEN GAUKROGER, DESCARTES: AN INTELLECTUAL BIOGRAPHY 116 (1995).

¹¹ See WOLF, *supra* note 8, at 2-3.

¹² See THOMAS S. KUHN, THE COPERNICAN REVOLUTION 197 (1996) (noting that Copernicus was a Catholic cleric who was friendly with members of the Catholic hierarchy).

¹³ If God created man in his image and at the center of the universe, the earth must be at the center as well. See RICHARD TARNAS, THE PASSION OF THE WESTERN MIND: UNDERSTANDING THE IDEAS THAT HAVE SHAPED OUR WORLD VIEW 253 (1991). In addition, as Martin Luther noted in criticizing Copernicus, "the fool will overturn the whole science of astronomy. But as the Holy Scripture states, Joshua bade the sun stand still and not the earth." See DOROTHY STIMSON, THE GRADUAL ACCEPTANCE OF THE COPERNICAN THEORY OF THE UNIVERSE 39 (1917) (citing the Martin Luther quote and explaining its scriptural reference to Joshua 10:10-15).

¹⁴ A preface to Copernicus' major manuscript, inserted without his knowledge, explained that heliocentricity is merely a convenient computational method that should not be taken seriously as a realistic account of the heavens. See TARNAS, *supra* note 13, at 252. The preface reads, in relevant part:

For it is sufficiently clear that this art is absolutely and profoundly ignorant of the causes of the apparent irregular movements. And if it constructs and thinks up causes—and it has certainly thought up a good many—nevertheless it does not think them up in order to persuade anyone of their truth but only in order that they may provide a correct basis for calculation.

Andrew Osiander, *To the Reader Concerning the Hypothesis of this Work*, in NICHOLAS COPERNICUS, ON THE REVOLUTIONS OF HEAVENLY SPHERES (1543), translated in STEPHEN HAWKING, ON THE SHOULDERS OF GIANTS 7 (2002).

Not all, however, were willing to adopt the convenient instrumental mantle. For example, when offered the instrumental approach as an escape from the wrath of the inquisition, Galileo eventually declined. See ROSENBERG, *supra* note 8, at 94-95.

¹⁵ See TARNAS, *supra* note 13, at 253.

¹⁶ See *id.* at 259.

¹⁷ See *id.* at 251-54 (describing the Catholic Church's original tolerance for Copernican theories and later repression in

beliefs that the Bible should be followed for its moral teachings rather than its astronomy, and that all religions and philosophies should coexist in tolerance and mutual understanding . . . received little enthusiasm from the Inquisition.”¹⁸

¶24 Although ultimately rejected by the Church, these efforts to avoid conflicts between Church and science would begin the process of creating a separate sphere for science. Science emerged as a realm focusing on understanding nature and the universe through human observation, using theories that the human mind can reason from those observations, and reaching conclusions that can be tested through further observations of the universe. It is centered on solving problems, and separated from inquiries related to morality and justice.

¶25 One could say that the need to separate from theology shaped the scientific sphere. Alternatively, one could say that the two spheres were able to separate because of their differing contours. In either case, it is clear that science settled into a separate space for itself based on observation and confirmation.

¶26 The same concepts that separated science from the Church would form the basis of separating science from philosophy.¹⁹ In particular, as science pulled away from theology, philosophers such as Francis Bacon in England and René Descartes in Continental Europe began to reconceptualize science and its relationship with both theology and philosophy.²⁰ They created a distinction between intellectual theories that followed from observation and experimentation and theories that were more remote.²¹ The former would be called natural philosophy while the latter would be called speculative philosophy or some other designation.²² Most important, natural philosophy should be an objective inquiry, one that is based on reliable methods of inquiry focusing on features that can be quantified.²³

¶27 By the end of the Seventeenth Century, natural philosophy, which we now call science, had carved out a space for itself strongly differentiated from theology and philosophy. The difference could be identified in terms of the types of questions to explore and the approach to those questions. Science would be an objective inquiry into natural phenomena focusing on solving practical problems and grounded in observation, experimentation, and empirical analysis. This would be distinct from philosophy, which would focus on abstract exploration through human reasoning, and from theology, which would concern spiritual enlightenment through divine revelation.

¶28 No sooner did science begin to separate itself out, than others began to emulate it. This was particularly true in the field of law where some legal thinkers reached out for science almost immediately.

¶29 By the late 1600s, for example, Gottfried Wilhelm Leibniz argued that law should be based on natural sciences such as geometry.²⁴ He created a legal code based on scientific principles intended for adoption throughout the Austro-Hungarian Empire and Europe, although he was unsuccessful in convincing the emperor Leopold I to enact the code.²⁵ What Leibniz saw in science was more than

response to pressure from Protestant reformers).

¹⁸ See *id.* at 253; see also GIORDANO BRUNO, THE ASH WEDNESDAY SUPPER 126 (Stanley L. Jaki trans., Mouton & Co. 1975) (1584) (explaining that the reason science conflicts with the Bible is because it is too difficult for the masses to understand, so everything was just simplified for their benefit: “the divine lawgiver does not care to speak on that level of truth by which the common folk would not profit”).

¹⁹ See WOLF, *supra* note 8, at 5-6.

²⁰ See, e.g., GAUKROGER, *supra* note 10, at 116 (describing in detail how Descartes took the Jesuit curriculum that he had studied in his youth, which combined natural philosophy, metaphysics, math, ethics, etc., and separated those fields); see also DESCARTES, *supra* note 10, at 21.

²¹ See WOLF, *supra* note 8, at 629-30.

²² See *id.* at 630.

²³ See Robert Hollinger, *Introduction to Part 6* of INTRODUCTORY READINGS IN THE PHILOSOPHY OF SCIENCE, *supra* note 3, at 481, 483-84 (discussing Newtonian science and describing René Descartes as the main architect of the epistemological and methodological revolution in science and philosophy).

²⁴ See ROGER BERKOWITZ, THE GIFT OF SCIENCE: LEIBNIZ AND THE MODERN LEGAL TRADITION 19 (2005); see also M.H. Hoeflich, *Law and Geometry: Legal Science from Leibniz to Langdell*, 30 AM. J. LEGAL HIST. 95, 99 (1986) (arguing that Leibniz should be given principal responsibility for developing the geometric paradigm in law). For a detailed description of more modern incarnations of the geometric ideal in legal thought, see Thomas C. Grey, *Langdell's Orthodoxy*, 45 U. PITT. L. REV. 1, 16-19 (1983).

²⁵ See BERKOWITZ, *supra* note 24, at 11-12; see also DONALD RUTHERFORD, LEIBNIZ AND THE RATIONAL ORDER OF

simply a way of organizing and synthesizing analysis. He saw the possibility of a systematic way of knowing the world, proceeding out of divine and rational first principles.²⁶ The legal system would operate with an abstract purpose which could be expressed in elemental and reliable theorems. The theorems could be applied to calculate all potential case combinations, allowing legislators to determine all proper outcomes in advance.²⁷ In this way, law could follow the insights of the science of the time, as it was emerging in a form separate from philosophy and theology.

¶30 The notion of what constitutes science and what it would mean to make law more scientific would vary across time and among scholars.²⁸ Nevertheless, law's attraction to science reaches almost back to the time when science separated itself out from other types of thought. What unites all of these attempts to reach for science is the view that science, in whatever form it takes, can solve the problems of law. Science stands on a pedestal as the "other" that will help law find itself.

¶31 Perhaps the greatest irony, however, is the place of honor and worship to which science has ascended. Science, which had the effect of freeing observation and interpretation from the grasp of the medieval church, looms as its own theocracy within law today.²⁹ This is certainly not what the men of the scientific revolution intended, nor is it necessarily what modern men and women of science would relish. Our misplaced faith in what some have called "science's ability to answer all questions and displace other ways of knowing,"³⁰ is not imposed from the scientific realm. It is not the scientific explorers who would have science ascend to these lofty heights. Rather, it is our desperation for solutions in law that leads us to place science upon this pedestal.

A. Science Confronted and Confounded

¶32 As described above, the Scientific Revolution brought both significant advances in science as well as an important shift in the conceptualization of science. Science emerged from this period as distinct from philosophy, which would focus on abstract exploration of topics such as existence and truth, and theology, which would focus on spiritual enlightenment.

¶33 Of course, science, philosophy, and theology cannot be so neatly distinguished. Despite the conceptual separation of these three spheres, the spaces of overlap would challenge the great minds of future generations. Philosophical explorations into the nature of truth, for example, can easily blend into questions relating to determining what information is reliable for science as well as into identifying the proper path for moral and spiritual enlightenment.

¶34 To borrow an analogy from science, the three spheres are like water, with its three forms as a liquid, a gas, and a solid. The water molecules interact differently within each form, creating structural variations on a molecular level. Despite these structural differences, there are places of overlap where the properties of the substance lie between those of the distinct forms.³¹ In other words, there are circumstances in which multiple forms of the substance coexist. Such is the

NATURE 240 (1995) (discussing the manifestation of divine wisdom in the physical realm).

²⁶ See BERKOWITZ, *supra* note 24, at 19.

²⁷ See *id.* at 35-38 (using Leibniz's combinatorial method for examining contract cases to explore Leibniz's theory of mathematical jurisprudence).

²⁸ See FELDMAN, *supra* note 1; Robin Feldman, *Law's Misguided Love Affair with Science*, MINN. J. L. SCI. & TECH. (forthcoming Winter 2008).

²⁹ See P.K. Feyerabend, *How to Defend Society Against Science*, in INTRODUCTORY READINGS IN THE PHILOSOPHY OF SCIENCE, *supra* note 3, at 54, 56 (comparing the broad society's reverence for the judgment of scientists with the reverence once held for bishops and cardinals).

³⁰ See ROSENBERG, *supra* note 8, at 7 (describing "scientism" in broader society); see also Robert Hollinger, *From Weber to Habermas*, in INTRODUCTORY READINGS IN THE PHILOSOPHY OF SCIENCE, *supra* note 3, at 539, 546 (noting that Habermas' early work developed a criticism of Weber's adherence to the doctrine of "scientism," which posits that only science is valid and rational and that other disciplines must adopt scientific methods to be considered rational knowledge); see also JÜRGEN HABERMAS, *TOWARD A RATIONAL SOCIETY: STUDENT PROTEST, SCIENCE, AND POLITICS* 64 (Jeremy J. Shapiro trans., Beacon Press 1971).

³¹ For example, consider the unusual behavior of the density of water near the freezing point. Liquid water is denser than ice, with water being most dense at four degrees Celsius. At zero degrees Celsius, solid ice forms. Between four and zero degrees, however, some of the water molecules begin to adopt an ice-like structure. In this temperature range the substance is still a liquid, but its density begins to resemble that of ice.

relationship of science, philosophy, and theology. They are technically distinct, but it is the spaces of overlap that provide some of the most interesting features.

¶35 It is indeed the spaces of overlap that would eventually confound those who tried to identify what is science in the twentieth century. This period witnessed nothing short of a revolution in thinking about the nature of science and how one should define things scientific.

B. The Twentieth Century Revolution

¶36 Across the march of history, different sciences became separated out from philosophy and theology. Astronomy led the way in the sixteenth century, followed by physics in the seventeenth, chemistry in the eighteenth, and finally biology in the nineteenth.³² Fields of science peeled off, one by one, as they became organized bodies of thought with more distinct boundaries and coherent frames of reference. Identifying these boundaries and determining when a science had fully emerged such that it should be considered a reliable science, as opposed to something else, however, could be tremendously challenging.

¶37 Until the middle of the twentieth century, the notion of what constituted reliable information in general, and reliable scientific information in particular, was based on the concept of logical positivism. This philosophical framework suggests that statements can be proven true only if they can be confirmed by experience.³³ True statements can be verified through experimentation, quantification, and sensory perception. Only the types of information that are testable through experimentation and observation should be considered the subject of science, rather than the subject of philosophy.³⁴ The logical positivism of the early twentieth century followed a logical tradition stretching back to Descartes and even to forms of Aristotelian thinking.³⁵ Pressing against the boundaries of this framework, however, philosophers of science in the middle of the century began trying to delineate what kinds of questions we can answer, which might fall within the realm of science, and what kinds of questions we cannot yet answer or will never be able to answer, which might fall within the realm of philosophy.³⁶ Exploration of these and other questions concerning the definition of science produced a revolution in thinking about the nature of the scientific enterprise.

¶38 The revolution began in earnest with the publication of Thomas Kuhn's book *The Structure of Scientific Revolutions*, which was described some time later as "the single most influential work on the philosophy of science that has been or will be written in this century"³⁷ and the "most heavily cited work in the second half of the twentieth century's absorption with science."³⁸ Kuhn's theories, described in this and later works, engendered a profound soul searching among scientists, or at the very least, a searching look by those who study it. As Kuhn and others challenged the age-old vision of science, the smallest, simplest descriptive questions became difficult to answer because they nested inside the larger, more prophetic ones.

¶39 Kuhn's explorations and those that followed exposed enormous gaps in our definitions of science. In fact, they completely undermined philosophy's confidence that it understood anything about science at all.³⁹ First, the new philosophers of science questioned whether there is any objectivity in science. If one is going to test a hypothesis, for example, how does one know whether

³² See WOLF, *supra* note 8, at 5-6; see also ROSENBERG, *supra* note 8, at 3 (noting that the history of science from the Greeks to the present is a history of one compartment of philosophy after another breaking away from philosophy and emerging as a separate discipline).

³³ See ROSENBERG, *supra* note 8, at 22-23 (describing logical positivism).

³⁴ See *id.* at 23.

³⁵ See Ernan McMullin, *Values in Science*, in INTRODUCTORY READINGS IN THE PHILOSOPHY OF SCIENCE, *supra* note 3, at 515 (describing the logicist tradition of logical positivism).

³⁶ See ROSENBERG, *supra* note 8, at 2-4 (describing the field of philosophy of science and differentiating it from science itself).

³⁷ See CLARK GLYMOUR, THEORY AND EVIDENCE 94 (1980) (describing and criticizing the approach launched by Kuhn); see also THOMAS S. KUHN, THE STRUCTURE OF SCIENTIFIC REVOLUTIONS (1962).

³⁸ See ROSENBERG, *supra* note 8, at 147.

³⁹ *Id.*

that hypothesis successfully passed the test? The choices made when scientists decide whether the available evidence is good enough to warrant acceptance of a hypothesis are themselves value-laden.⁴⁰ “No puzzle solving enterprise can exist unless its practitioners share criteria which, for that group and for that time, determine when a particular puzzle has been solved.”⁴¹ Distinctions between reliable and unreliable knowledge and between good and bad methods are at least partly value judgments.⁴²

¶40 Objectivity, said Kuhn, consists not in the correspondence of our theories to the world, but in the fact that the members of the scientific community all agree about the theory or ways to evaluate the theory, both of which are completely subjective.⁴³ Normally, scientists take for granted the background theories of the day and simply try to solve puzzles based on other assumptions and models.⁴⁴

¶41 The common view of scientific change is that scientists, faced with increasing evidence of problems in the observational data, are inspired to search out better explanations. This search leads them to re-evaluate the theories that have come before, resulting in a shift. Kuhn and others argued that scientific revolutions generally do not occur this way. First, scientists do not operate in a world of perfection in which observable evidence generally matches available theories. No theory ever fits all the available evidence. Rather, scientists talk about anomalies and recalcitrant instances, looking for ways to refine the prevailing paradigms rather than disposing of them.⁴⁵ It would be folly for scientists to operate otherwise, given that the anomalies themselves may turn out to be erroneous.⁴⁶

¶42 In addition, scientists now generally agree that scientific theories *cannot* be proven by observational evidence, although the probability that the theories are accurate can be strongly enhanced by that evidence.⁴⁷ The problem is that we can never be certain whether we are working from a sufficient amount of observation. For example, Newton’s theories of how particles of matter attract other particles of matter are based on observations of planetary movements generalized to all matter in the universe. Our observations necessarily are limited to certain bodies during certain periods of time. It is entirely possible, however, that while our observations are correct, our theories are wrong because we simply haven’t observed enough matter in the universe to know whether our concept of gravity is accurate or whether there are entirely different forces at work.

¶43 Others have questioned whether one can ever have faith in observations at all. Most of our scientific observations are not based on direct perception but on scientific instruments. We believe that a particular substance has a particular temperature, but that is based on the indirect observation of mercury rising in a thermometer rather than any direct observation. What then would count as a direct observation? Perhaps seeing a dog walking across the street would suffice. But then, the sun appears to walk across the sky, which is an observation that scientists believe to be inaccurate. How then can perception ever be reliable?

⁴⁰ See Richard Rudner, *The Scientist Qua Scientist Makes Value Judgments*, in *INTRODUCTORY READINGS IN THE PHILOSOPHY OF SCIENCE*, *supra* note 3, at 492, 492-98.

⁴¹ Thomas S. Kuhn, *The Sciences as Puzzle-Solving Traditions*, in *CONCEPTIONS OF INQUIRY* 107, 110 (Stuart Brown, John Fauvel, & Ruth Finnegan eds., Routledge 1981).

⁴² See Hollinger, *supra* note 23, at 485.

⁴³ See THOMAS S. KUHN, *THE ESSENTIAL TENSION: SELECTED STUDIES IN SCIENTIFIC TRADITION AND CHANGE* 320-39 (1977).

⁴⁴ See CURD & COVER, *supra* note 8, at 67 (describing Kuhn’s book, *THE STRUCTURE OF SCIENTIFIC REVOLUTIONS*, *supra* note 37).

⁴⁵ See Imre Lakatos, *Science and Pseudo-Science*, in *CONCEPTIONS OF INQUIRY*, *supra* note 41, at 114, 118 (“[S]cientists talk about anomalies, recalcitrant instances, not refutations. History of Science, of course, is full of accounts of how crucial experiments allegedly killed theories.”); see also Kuhn, *The Sciences as Puzzle-Solving Traditions*, in *CONCEPTIONS OF INQUIRY*, *supra* note 41, at 112 (discussing the importance of unexpected results in defining the astronomical research tradition).

⁴⁶ See Kuhn, *supra* note 41, at 112 (noting that if observations did not match a scientific prediction, a scientist might assume that “the data were at fault: old observations could be re-examined and new measurements made”); cf. Lakatos, *supra* note 45, at 118 (“Science is not simply trial and error, a series of conjectures and refutations. ‘All swans are white’ may be falsified by the discovery of one black swan. But such trivial trial and error does not rank as science.”).

⁴⁷ See CURD & COVER, *supra* note 8, at 69 (The explanation following in the text, using Newton’s theories to demonstrate why we can never be certain of scientific theories, is described and set out more fully therein.).

¶44 Most important, Kuhn pointed out that periods of scientific revolution often challenge the image that science builds carefully on what has gone before, expanding to new horizons as the available evidence increasingly raises questions about the theories that have come before. Rather, new theories frequently appear before the old ones have been refuted.⁴⁸ Moreover, once the revolution occurs, it may require an entire reformulation, rather than building upon prior knowledge.⁴⁹ Thus, even in times of scientific revolution, science utterly fails to live up to the image of a progressive endeavor, carefully testing established theories and building upon what has come before.

¶45 Others attacked the notion that our scientific theories are reliably structured from empirical observation. Sciences operate by making generalizations from directly observable items or even from non-observable items such as electrons.⁵⁰ As Popper pointed out, no rule can ever guarantee that a generalization, even one inferred from a direct observation, is true.⁵¹ No matter how true that observation may be, the generalization may be misguided. Induction, therefore, is a myth.⁵²

¶46 Even observation itself may be unreliable. Not only is it limited by whatever instruments we have available at the time, it is also shaped by the experiences that we bring to the observation and influenced by our cultural expectations. As one author so eloquently explained, “Contrast the freshman’s view of college with that of his ancient tutor. Compare a man’s first glance at the motor of his car with a similar glance ten exasperating years later.”⁵³ The items examined are the same, and yet we interpret them differently based on experience and expectations.

¶47 To some extent, these arguments can be countered by the notion that we should be able to control for these variations by designing something consistent to observe and by factoring out our individual distortions. Although a wonderful concept in theory, the new philosophers of science challenged the notion that human beings are ever capable of such unsullied thought, freezing from one’s mind the influences arising from one’s personal experiences and from the subtle perspectives of the scientific community.⁵⁴

¶48 I would call these philosophers Scientific Subjectivists.⁵⁵ Scientific Subjectivists argued that the prevailing definition of science as a reliable method of testing and organizing society’s knowledge and building upon that knowledge, simply cannot stand up to a rigorous examination. As with many deconstructionist movements, however, the problem is that while the new philosophy devastated the prevailing view of what science is, it created no other definition of what science could be. Most importantly, it left no coherent way to distinguish science from non-science. If science is not what we think it is, how can it claim to be any different from astrology, theology, or even magic?

¶49 A number of philosophers from this twentieth century period tried to construct alternative definitions of what constitutes science. Popper, for example, suggested that the hallmark of true

⁴⁸ See *id.* at 67 (describing Kuhn’s book, *THE STRUCTURE OF SCIENTIFIC REVOLUTIONS*, *supra* note 37).

⁴⁹ See KUHNS, *THE STRUCTURE OF SCIENTIFIC REVOLUTIONS*, *supra* note 37, at 98 (describing certain types of revolutionary changes in science and noting that it would be hard to imagine how new theories could arise without this type of destructive changes in belief structures). See also CURD & COVER, *supra* note 8, at 227 (explaining Kuhn’s denial of cumulativity and the notion that scientific theories are moving closer to some objective theory-independent truth); Douglas H. Erwin, *Darwin Still Rules, but Some Biologists Dream of a Paradigm Shift*, N.Y. TIMES, June 27, 2007, at F2, available at <http://www.nytimes.com/2007/06/26/science/26essay.html> (suggesting that the Darwinian notion of selection may soon be replaced by a new paradigm of evolution based on mutation).

⁵⁰ See Michael Ruse, *Creation-Science Is Not Science*, 7 SCL., TECH., & HUM. VALUES 72, 72-73 (1982); see also Stephen Toulmin, *Do Sub-Microscopic Entities Exist?*, in *INTRODUCTORY READINGS IN THE PHILOSOPHY OF SCIENCE*, *supra* note 3, at 358, 358-60 (discussing whether a neutrino “exists” and what it would take to prove or produce it).

⁵¹ See Karl R. Popper, *Philosophy of Science: A Personal Report*, in *BRITISH PHILOSOPHY IN THE MID-CENTURY* 155, 167 (C.A. Mace ed., The MacMillan Company 1957) (stating that “we can say that theories can never be inferred from observational statements, or rationally justified by them”).

⁵² See Popper, *supra* note 51, at 166 (agreeing with Hume’s proposition that “there can be no valid logical argument allowing us to establish ‘that those instances, of which we have had no experience, resemble those, of which we have had experience’”).

⁵³ See N. R. Hanson, *Observation*, in *INTRODUCTORY READINGS IN THE PHILOSOPHY OF SCIENCE*, *supra* note 3, at 339, 345.

⁵⁴ For extreme examples of this phenomenon, see Fritz Machlup, *Are the Social Sciences Really Inferior?*, in *INTRODUCTORY READINGS IN THE PHILOSOPHY OF SCIENCE*, *supra* note 3, at 135, 138-39 (noting that German mathematicians and physicists rejected what they considered Jewish theorems such as Einstein’s relativity and Russian biologists stuck to an inaccurate mutation theory due to politics); see also ROSENBERG, *supra* note 8, at 179-84 (describing feminist and race theory critiques of science).

⁵⁵ This is not a term found in philosophy of science literature, but I believe it captures the essence of their perspectives.

science is falsification. Those advancing a particular theory should be able to specify in advance something that the theory could predict and for which the theorist would be willing to abandon the theory if the prediction failed.⁵⁶ A science should be able to make risky predictions, ones that we would not expect without the theory.⁵⁷

¶50 Falsification sounds like a good bedrock principle for a science, but it was a failure. As Thagard points out, the falsification principle either ruled out most of science as unscientific or ruled out nothing.⁵⁸

¶51 The falsification principle has been battered into the ground across time, so I will only describe a few of the refutations here.⁵⁹ First, it is simply not the case that any theories agree with all of the observable facts.⁶⁰ As the Nobel Prize recipient Francis Crick noted, “[a]ny theory that fits all the facts is bound to be wrong, since some of the facts will be misleading or just wrong in themselves.”⁶¹ One cannot abandon a theory whenever it makes a false prediction because science is a complicated undertaking and one cannot know if the falsification itself is correct.⁶²

¶52 In addition, everything that we think of as science could be falsified yet still be true. For example, if we re-enact Newton’s apple scenario and the apple drifts away instead, the observation does not necessarily refute the laws of gravity. Some other force may have been in operation at the time.⁶³

¶53 Most important, although Popper’s falsification principle was intended to distinguish between science and pseudo-science, falsification does not describe the way scientists actually operate. If science is about what we perceive and what we can verify, the definition seems to leave out a lot of how science has actually operated and what scientists do. As Lakatos pointed out, “[h]ad Popper ever asked a Newtonian scientist under what experimental conditions he would abandon Newtonian theory, some Newtonian scientists would have been exactly as nonplussed as are some Marxists.”⁶⁴

¶54 To some extent, the works of those such as Popper arose out of a desire to separate what they saw as true science from pretenders to the throne, including Marxism, Freudianism, and astrology.⁶⁵ This orientation hampers the enterprise. Definitions crafted with an eye towards distinguishing particular examples become less workable as general rules. Nevertheless, others following Popper have been equally unable to delineate a coherent definition of what constitutes science. The

⁵⁶ See Lakatos, *supra* note 45, at 117-18 (describing Popper).

⁵⁷ See Popper, *supra* note 51, at 159 (arguing that confirmations of a theory should only count if “they are the result of *risky predictions*; that is to say, if, unenlightened by the theory in question, we should have expected an event which was incompatible with the theory—an event which, had it happened, would have refuted the theory”).

⁵⁸ See Paul R. Thagard, *Why Astrology Is a Pseudoscience*, 1 PROCEEDINGS OF THE BIENNIAL MEETING OF THE PHILOSOPHY OF SCIENCE ASSOCIATION 223, 225 (1978); cf. ROSENBERG, *supra* note 8, at 137 (noting that science cannot live up to its own definition of rigor).

⁵⁹ See Thagard, *supra* note 58, at 225 (explaining that the vicissitudes of the verification principles are well-known); Larry Laudan, *Commentary: Science at the Bar – Causes for Concern*, 7 SCL., TECH. & HUM. VALUES 16, 18 (1982) at 16, 18 (noting that numerous authors have shown that “the requirements of testability, revisability, and falsification are exceedingly weak requirements”).

⁶⁰ See Philipp G. Frank, *The Variety of Reasons for the Acceptance of Scientific Theories*, in INTRODUCTORY READINGS IN THE PHILOSOPHY OF SCIENCE, *supra* note 3, at 465 (noting that “[i]t has never happened that all the conclusions drawn from a theory have agreed with the observable facts”).

⁶¹ See Frank Barlow, *Introduction to WIDO, THE CARMEN DE HASTINGAE PROELIO OF GUY, BISHOP OF AMIEN xi* (Frank Barlow trans., Oxford University Press 1999) (quoting Francis Crick).

⁶² See CURD & COVER, *supra* note 8, at 64 (noting the abandonment problem); Wolpert, *supra* note 5, at 295 (noting that falsifications may be wrong).

⁶³ See Philip Kitcher, *Believing Where We Cannot Prove*, in INTRODUCTORY READINGS IN THE PHILOSOPHY OF SCIENCE, *supra* note 3, at 76, 87 (describing the Newton apple scenario and its impact on the falsifiability principle).

⁶⁴ See Lakatos, *supra* note 45, at 118.

⁶⁵ See Popper, *supra* note 51, at 156-57 (explaining that he felt “these other three theories [Marxism, psycho-analysis, and individual psychology] posed as sciences while in fact they were of the character of primitive myths rather than of science; that they resembled astrology rather than astronomy”); see also Thagard, *supra* note 58, at 229 (describing the decline of astrology—once held to be a science—to the status of an unpromising project, and eventually, a pseudoscience); Carl G. Hempel, *Two Basic Types of Scientific Explanation*, in CURD & COVER, *supra* note 8, at 685-94 (comparing Deductive and Probabilistic explanations, and pointing to Freud’s vagueness in support of the notion that psychoanalysis is not a science).

definitions proposed have proven incapable of separating astronomy from astrology⁶⁶ or creation science from evolution.⁶⁷

¶55 Part of the problem flows from inconsistent visions of what we are trying to define. For example, are we adopting a normative view or a descriptive view? In other words, is this what science is or what science, at its best, ought to be?

¶56 Moreover, in trying to define science, are we talking about 1) a method of obtaining information, 2) the information gained from that method, or 3) the intent of those engaging in the method? Different definitions of science seem variously grounded in each. For some, the objectivity of science refers to the truth and character of the information obtained, and for others, the objectivity of science refers to the reliability of the method.⁶⁸ Still others would identify science in ways that seem to focus on the intent of those who practice the art. For example, some scholars speak of science as the attainment of truth and the pursuit of knowledge, or at least the closest possible realization of that.⁶⁹ These confusions contribute to the great muddle of trying to define science.

¶57 This frustrating exercise has created a tendency towards extremes, even among scientists themselves. When pressed to abandon the notion of science as certain and infallible, some scientists shift to a forlorn skepticism, viewing their endeavors as no more than a game played with arbitrary rules or an enterprise based ultimately on faith.⁷⁰ Some philosophers and sociologists would go even further, suggesting that we abandon the idea of science as a separate or privileged domain of inquiry and recognize it as no different from any other set of myths or beliefs.⁷¹

¶58 Bruno Latour, a philosopher of science, describes a striking example of this phenomenon in the opening of his book, *Essays on the Reality of Science Studies*.⁷² In dramatic prose, Latour recounts his experience at a conference in which a scientist quietly took him aside, and after taking a deep breath asked him, “Do you believe in reality?” and “Do we [scientists] know more than we used to?”⁷³ Through this and other conversations, Latour came to understand that what he had always thought of as adding realism to science was being viewed by scientists as a threat to the very calling of science.

¶59 Latour was shocked. “How [could] this misunderstanding come about? How could I have lived long enough to be asked in all seriousness this incredible question: ‘Do you believe in reality?’”⁷⁴

C. An Uneasy Truce

To answer the question “What is science?” is almost as presumptuous as to try to state the meaning of life itself.

- John Ziman⁷⁵

¶60 Retreating from the edges of oblivion and despair, philosophers of science have settled into an uneasy truce. After all, “applications of science to technologies such as electronics or jet aircraft

⁶⁶ See PHILOSOPHY OF SCIENCE AND THE OCCULT 11 (Patrick Grim ed., 1982) (noting that most philosophers take astrology as a “prime example of pseudo-science . . . however much they may disagree as to precisely *why* astrology is pseudo-scientific or as precisely what astrology’s faults are” (emphasis in original)).

⁶⁷ See Laudan, *supra* note 59, at 17 (arguing that in declaring creationism non-scientific, a federal trial court may have reached the right result but for unsupportable reasons).

⁶⁸ See HELEN E. LONGINO, SCIENCE AS SOCIAL KNOWLEDGE: VALUES & OBJECTIVITY IN SCIENTIFIC INQUIRY 63 (1990) (explaining that those who believe science provides objectivity use two different senses of the word).

⁶⁹ See, e.g., E.D. Klemke, *Introduction to Part 1* of INTRODUCTORY READINGS IN THE PHILOSOPHY OF SCIENCE, *supra* note 3, at 29, 31.

⁷⁰ Kitcher, *supra* note 63, at 80 (describing philosopher George Berkeley’s use of the term “forlorn skepticism” and expanding on the way scientists react to challenges by philosophers of science).

⁷¹ See Wolpert, *supra* note 5, at 295.

⁷² The following episode is recounted in BRUNO LATOUR, PANDORA’S HOPE: ESSAYS ON THE REALITY OF SCIENCE STUDIES 1-3 (Harvard University Press 1999).

⁷³ See *id.* at 1.

⁷⁴ *Id.* at 3.

⁷⁵ John Ziman, *What is Science?*, in INTRODUCTORY READINGS IN THE PHILOSOPHY OF SCIENCE, *supra* note 3, at 48, 48.

should give us all some confidence that reality is involved” in the enterprise of science, even if we cannot definitively identify the boundaries of that enterprise.⁷⁶ The approach begins with a certain awe and humility, a recognition of the difficulty of defining science at all. With this in mind, a number of scholars have proposed various groupings of elements that would delineate science from non-science endeavors. The elements are intended to roughly represent shared values of the scientific community.

¶61 One cannot overemphasize the imperfection of the endeavor. No elements, either individually or as a group, can accurately separate what we think of as science from non-science. Nevertheless, on the whole, these criteria give some comfort that an approach or a conclusion is more likely than not to fall within what we consider science.

¶62 Various scholars would choose different elements for the group. Some would suggest five elements, others three, and still others nine.⁷⁷ These elements would apply to test both whether a field can be called science and whether individual theories within the field are reasonably scientific. As a general matter, the approaches focus on the following types of issues. First, are they testable in the sense that they are able to be tested? In other words, are they based on observations from the physical world that can be quantified and independently verified?

¶63 Second, do they have predictive capacity? In other words, are they not just capable of being tested, but also capable of making predictions that we can test for accuracy and consistency of the theories? Although Popper’s falsifiability principle no longer stands as the sole hallmark of a true science, it is still useful to consider whether a science or a theory can be put to the test of prediction. For example, our sticks and elephants could be tested by halting the sticks and waiting for the elephants to rampage.

¶64 Third, how comprehensive are they? Do they explain things that other theories have been unable to explain, and do they pull together disparate threads of the particular field or even a group of fields? Watson and Crick’s discovery of DNA, for example, also explained the fundamental laws of Mendelian genetics, that is, how hereditary traits travel from generation to generation.⁷⁸

¶65 Fourth, are they fruitful? Do they give rise to other new theories that continue to advance the understanding of the field, or are the theories focused on accommodating known facts?⁷⁹ This is a variation on the notion of progressivity. In other words, can the theories serve as the foundation for future ideas?

¶66 And finally, following a long-held principle of science, are they simple? Are they elegant and parsimonious, or do they require us to take many mental detours to follow them? A variation on this theme is the notion of whether the theories are understandable given what we think we can rely on. Do they follow common sense, or do they require us to substantially suspend our disbelief?

¶67 It is critical to understand that all of these elements have significant weaknesses for defining science. While it is important to base scientific theory on observations from the physical world, science is frequently incomplete. Thagard has pointed out, for example, that there was no physical foundation for the continental drift theory when it was proposed, and yet it has become an important part of geologic science.⁸⁰

⁷⁶ Helen Reece, *Editor’s Introduction to LAW AND SCIENCE: CURRENT LEGAL ISSUES VOL. 1*, *supra* note 5, at ix (describing Lewis Wolpert’s argument).

⁷⁷ See THOMAS S. KUHN, *THE ESSENTIAL TENSION: SELECTED STUDIES IN SCIENTIFIC TRADITION AND CHANGE* 321-22 (The University of Chicago Press 1977) (listing accuracy, consistency, scope, simplicity, and fruitfulness.); Machlup, *supra* note 54, at 136 (listing invariability of observations, objectivity of observations and explanations, verifiability of hypotheses, exactness of findings, measurability of phenomena, constancy of numerical relationships, predictability of future events, distance from everyday experience, standards of admissions and requirements); Klemke, *supra* note 69, at 32 (adapting Herbert Feigl’s suggestions to come up with intersubjective testability, reliability, definiteness and precision, coherence or systematic character, and comprehensiveness or scope); Thagard, *supra* note 58, at 227 (nesting the various elements into three broad groupings related to theory, community, and historical context); see also CURD & COVER, *supra* note 8, at 228-30 (describing Kuhn’s five shared epistemic values).

⁷⁸ See ROSENBERG, *supra* note 8, at 77.

⁷⁹ See Lakatos, *supra* note 45, at 117-20 (comparing Newtonian science to Marxism).

⁸⁰ See Thagard, *supra* note 58, at 225.

¶68 Similarly, predictive capacity is important, but it is no guarantee of the accuracy of a theory. The theory may simply be based on the wrong underlying concepts. For example, some acupuncture approaches are based on the notion of rerouting the forces of the “chi” of the human body.⁸¹ Suppose that acupuncture turns out to be effective for a reason entirely unrelated to any notion of chi—a useful therapy with a non-useful explanation. In that case, the field might have predictive capacity and yet still be inaccurate. Moreover, not all valuable scientific theories are predictive, particularly at the time of their inception. The Copernican theories were a breakthrough in explanation, although they were no better than their competitors at prediction.⁸²

¶69 A comprehensive theory that can pull together a number of threads is particularly valuable, but lack of comprehensiveness should not disqualify a theory. The scientist who theorizes that invisible bugs called “crobres” may be making us sick would not be able to explain all disease processes but would still have made an important and scientifically valid contribution.⁸³

¶70 Finally, simplicity and common sense remain desirable qualities of good science. Nevertheless, these values cannot always be satisfied in science. One has to suspend a great deal of disbelief to understand particle and wave theory, not to mention the notion that the earth moves around the sun.⁸⁴

¶71 On the whole, the vision of science among scientists and philosophers of science is framed as an effort to understand what is real and true in an enduring sense. The effort may be imperfect, limited as it must necessarily be by the imperfect beings who engage in the process. We may have difficulty recognizing what is true in the world around us. Indeed, we may be entirely incapable of recognizing it, but that does not mean the reality does not exist. There is circularity in science because what we define as the way to take us there and how we determine when we get there are both subjective, but this is different from the question of whether there is a “there” to get to.

¶72 Throughout this process, however, it is critical to recognize weaknesses in the notion that the method of obtaining information necessarily dictates the truth of the results. A theory may appear through induction, intuition, or a pure guess. Myths may contain kernels of truth and scientific theory may have much nonsense in it.⁸⁵ Proper scientific method or lack thereof does not necessarily correlate with the value of an insight, although proper scientific method can certainly help test the theory proposed.⁸⁶

¶73 Even in terms of testing theories, modern scientists do not claim that their theories are true. Rather, they speak of a theory as being “well-supported” or “rationally acceptable.”⁸⁷ When scientists say that they accept a theory, they may mean that they believe that the theory is “the best-supported of the alternatives available” or that it offers the most fruitful possibilities for research in the immediate future.⁸⁸ The most we hope for in science is not proof of truth or falsehood, but some confidence that a hypothesis is true more likely than not, or perhaps just useful given what we know at the moment.⁸⁹ This more modest goal is not at all what law dreams of when it reaches for science

⁸¹ See GABRIEL STUX ET AL, *BASICS OF ACUPUNCTURE* 88-89 (K.A. Sahn trans., 5th ed., Springer 2003).

⁸² See Ernan McMullin, *Rationality and Paradigm Change in Science*, in *WORLD CHANGES: THOMAS KUHN AND THE NATURE OF SCIENCE* 55, 74 (Paul Horwich ed., 1993).

⁸³ See Maxwell, *supra* note 3, at 363-65.

⁸⁴ See Frank, *supra* note 60, at 468-69 (noting that Copernican theories were not only non-natural but were “a serious violation of the rule to keep the principles of science as close to common sense as possible”).

⁸⁵ See Popper, *supra* note 51, at 162 (“[A]ll (or nearly all) scientific theories originate from myths.”); see also Thagard, *supra* note 58, at 223, 225 (noting that medicine and chemistry had magical origins); Lakatos, *supra* note 45, at 115 (noting that “a statement may be pseudoscientific even if it is eminently ‘plausible’ and everybody believes in it, and it may be scientifically valuable even if it is unbelievable and nobody believes in it,” given that a theory may “be of supreme scientific value even if no one understands it, let alone believes in it”).

⁸⁶ See Klemke, *supra* note 69, at 35 (describing newer visions of science in light of Popper’s criticisms).

⁸⁷ See McMullin, *supra* note 35, at 519.

⁸⁸ See *id.* at 520.

⁸⁹ See A. David Kline, *Introduction to Part 5* of *INTRODUCTORY READINGS IN THE PHILOSOPHY OF SCIENCE*, *supra* note 3, at 397, 402. Interestingly, this movement away from determinism mirrors recent developments in math and physics. In quantum physics, for example, the question of whether a single proton will emit an alpha particle at a particular time is a question of probabilities. For a description of these scientific advancements and their implications for philosophy of science, see ROSENBERG,

to solve our problems. It is hard to imagine putting someone in jail on the basis that the evidence is the best we have at the moment and makes somewhat more sense than the available alternatives.

III. MISUNDERSTANDING THE LIMITS OF SCIENCE

¶74 The revolution in modern views of science seems to have gone largely unnoticed in law. Judges and legal scholars do talk about what counts as “good” science. There is no mention, however, of the fact that we might not be able to define what science is at all, at least not in a way that definitively separates it from nonscience.

¶75 Failure to understand the limitations of science creates tremendous distortions when we try to make law more scientific or to let scientists solve our legal issues. On one level, the problem plays out as a misuse of science and scientific information.⁹⁰ Science begins with observations and theories that are rationally acceptable and well-supported, a much less exacting standard than certainty and infallibility. Ignoring these qualifications, law tries to translate science into social and legal conclusions, without understanding the perils of that translation.⁹¹

¶76 I saw a striking example of this in a recent talk by a young scholar. The scholar was discussing the law’s refusal to treat gifts the same way it treats other types of voluntary contracts, and the notion that law should not interfere in some types of personal interactions to avoid tainting the emotional content of those behaviors. The scholar excitedly pointed to fMRI results showing that when people give gifts, their reactions involve the same portion of the brain that appears to be active when people receive rewards. Thus, the scholar claimed that gifts should be treated in the same way as other self-interested transactions because the emotional content is analogous.

¶77 The claim is a tremendous leap from a tiny amount of data. The fact that blood flow increases in the same general area of the brain during two activities tells us very little about the specific neural processes at work, let alone about the emotional impact of the actions. It certainly does not give us sufficient information to build a legal regime.

¶78 Part of the problem when legal actors try to apply this type of research lies in understanding the difference between finding a statistically significant result and finding a result that will hold true in all cases or even almost all cases.⁹² For example, imagine that we are testing the hypothesis that subjects who are lying will light up what we designate as the red portion of the brain during a scan. The study will compare an experimental group and a control group. A valid study, properly designed, might find that those who are lying light up the red portion of the brain in a manner that is statistically significant when compared to the control group’s results. There will, however, be significant overlap in the results. Some in the control group will have had red-portion brain activity, and some of the people who were lying will have had no red-portion activity.

¶79 The notion of statistical significance is itself a misleading concept. Although certainly not a problem in the small scale brain scan studies, given a large enough sample, even minor differences will result in a finding of statistical significance.⁹³ A frequent error in social science is to confuse finding a statistically significant difference with finding that the difference is important.⁹⁴ If social scientists fall prey to this error, one should not be surprised to see the problem magnified when social science research reaches the courts.

supra note 8, at 9-11.

⁹⁰ See sources cited *supra* note 1.

⁹¹ See SHEILA JASANOFF, SCIENCE AT THE BAR: LAW, SCIENCE, AND TECHNOLOGY IN AMERICA, at xiv (1995) (noting that “scientific claims, especially those that are implicated in legal controversies . . . are . . . contingent on particular localized circumstances, and freighted with buried presumptions?”).

⁹² The hypothetical explained in this paragraph is derived from an excellent explanation in Stephen J. Morse, *Brain Overclaim Syndrome and Criminal Responsibility: A Diagnostic Note*, 3 OHIO ST. J. CRIM. L. 397, 403-04 (2006).

⁹³ See John R. Allison & Thomas W. Sager, *Valuable Patents Redux: On the Enduring Merit of Using Patent Characteristics to Identify Valuable Patents*, 85 TEX. L. REV. 1769, 1779 (2007).

⁹⁴ See Allison & Sager, *supra* note 93, at 1779.

¶80 Most important, finding brain correlations is only a tiny part of understanding the complexities of why that brain activity is occurring. As one scholar has noted:

Discovering the neural correlates of mental phenomena does not tell us how these phenomena are possible For example, the brains of late adolescents are almost certainly the same around the globe—holding nutrition and the like constant—but the rates of behaviors associated with immature adolescent brains, such as impulsive criminality, vary widely from place to place and from time to time. Monolithic brain explanation of complex behavior is almost always radically incomplete.⁹⁵

¶81 One could argue that we are merely talking about the gap between what is ideal and what is realistic. We understand what science might offer in the ideal, and we also understand its boundaries and limitations. Despite the limitations, we might still want to operate within those boundaries, maximizing the effects of what we can gain.

¶82 The problem, however, involves more than just misuse of science and scientific evidence. In addition to an inaccurate definition of science, law has an inaccurate vision of what science can do for us, given the nature of law. We are frequently led astray by the fervent hope that science can make law into something it is not.

IV. THE CHANGING NATURE OF LAW

¶83 In determining how to use science appropriately in the domain of law, one must consider not only the definition of science but the nature of law itself. This section will focus particularly on the unfolding of case law. This is not to suggest that legislation and administration are any less valid as expressions of the legal process. They do, however, involve specialized considerations beyond the legal behaviors that are the focus of this article.

¶84 The art of law involves taking prior authorities and distilling a common logic that can extend to new circumstances.⁹⁶ It is not a scientific expedition but rather a delicate dance of interpretation and adaptation. This enterprise involves identifying relevant groupings that provide comparisons, choosing among the conflicting analytic frameworks sets of logic that might emerge, and arguing persuasively for that choice.

¶85 In this process, one cannot overestimate the importance of the constant stream of new issues arising in case law. Despite the massive volume of laws and cases, courts are continually faced with new circumstances and new legal issues for two reasons. First, society itself is constantly changing. The domain of interstate commerce, for example, takes on an entirely different dimension with the invention of automotive transport.⁹⁷ Similarly, the question of what constitutes fair use of one's own copy of a recording must be analyzed differently when anyone with a computer can remix the sounds of the recording.

¶86 Consider an example from trademark law. Trademark law protects a trademark holder from others who would use the protected mark in a way that creates consumer confusion.⁹⁸ The arrival of the Internet, however, creates a new level of complexity for the notion of consumer confusion. Suppose I sell cars and operate a web site advertising my cars. Can I design my web site so that Internet search engines offer my site as one of the results when someone enters "Toyota" as a search term? Am I violating trademark law even if those who visit my site never see the word "Toyota" and have full knowledge that they will go to a competitor's site rather than Toyota's when they click on a

⁹⁵ See Morse, *supra* note 93, at 404.

⁹⁶ Cf. ANTONIN SCALIA, A MATTER OF INTERPRETATION: FEDERAL COURTS AND THE LAW, 8-9 (1997) (comparing the growth of the common law to a Scrabble board in that no rule previously announced may be removed but qualifications may be added: "The first case lays on the board . . . and the game continues.").

⁹⁷ See *Ollman v. Evans*, 750 F.2d 970, 995-96 (D.C. Cir. 1984) (Bork, J., concurring), *cert. denied*, 471 U.S. 1127 (1985).

Although, in modern American case law, authorities include mainly prior cases and legislation, at times in our history, custom and practice have played a greater role. See Lawrence Lessig, *Fidelity and Constraint*, 65 *FORDHAM L. REV.* 1365, 1403 (1997) (noting that prior to 1870, custom held a more central focus in American judicial decision making).

⁹⁸ See, e.g., *Qualitex Co. v. Jacobson Prods. Co.*, 514 U.S. 159, 162, 173 (1995) (discussing the Lanham Act).

link to my site?⁹⁹ In other words, can trademark law protect Toyota's interests even when, from the consumer's perspective, there is no use of the mark and no confusion? One could not have even contemplated this question before the invention of the Internet and the advent of search engines.¹⁰⁰

¶87 It is not just technological change but also social change that creates new issues for the courts.¹⁰¹ Questions concerning fathers' rights and grandparents' rights were unlikely to arise before the dramatic changes in the family unit in American society in the second half of the 20th century. This constant march of technological and social change ensures a steady stream of new issues for the courts.

¶88 Most importantly, legal issues are constantly new because the law itself drives both behavior and legal argument into new areas. Judges set boundaries based on the case in front of them. Those wishing to escape the constraints will naturally look for open territory, the interstices among those things that have been decided. In this way, courts are continually driven to evaluate new questions, adapting and interpreting old precedents. The challenge in law is law's tendency to expand into undefined areas and its capacity to move outside of whatever structures and explanations have been developed.

¶89 Consider an example from employment law. In the 1980s and 1990s, federal courts ruled that employers are strictly liable for sexual harassment that arises from hostile environments created by supervisors.¹⁰² Employers responded by developing internal policies and investigation procedures to find and address bad behavior by supervisors. With this apparatus in place, employers asked the courts to create an affirmative defense to strict liability. The defense would arise in cases in which employers had created adequate procedures, but the complaining employee had failed to take advantage of what the employer provided. The Supreme Court complied, creating a new defense in response to new forms of corporate behavior.¹⁰³ In this example, therefore, both human behavior and legal argument sought out available openings in existing case law, and the courts were faced with novel issues.

¶90 This is not to suggest that every case is new. Some legal issues will fall squarely within precedent. Nevertheless, the path of law inevitably moves towards the new and undecided. The art of law involves adapting to those changed circumstances within the framework of what has gone before.

¶91 Scientific rules are particularly ill-suited to this process of adaptation.¹⁰⁴ If legal actors lack sufficient information about a rule to both adapt it and to challenge those adaptations, the use of that rule will interfere with the unfolding of the legal process. The lack of analysis gives us insufficient information upon which to build and develop legal theories, leaving us to cling to rigid lines of demarcation instead. Thus, importing science, which embodies assumptions and shared understandings beyond the legal realm, hinders the process of doctrinal development.

¶92 Most important, when we borrow from science to establish legal rules, we assume that the science we are importing is based on certainty and solidity. It is easy to assure ourselves that we have found an enduring structure while ending up with no more than the illusion of reasonable resolution. The literature on the interface between law and science is replete with examples.¹⁰⁵

⁹⁹ See Margreth Barrett, *Internet Trademark Suits and the Demise of "Trademark Use,"* 39 UC DAVIS L. REV. 371, 423-33 (2006) (discussing metatag use); see also *Brookfield Commc'ns, Inc. v. West Coast Entm't Corp.*, 174 F.3d 1036, 1045 (9th Cir. 1999); *Bihari v. Gross*, 119 F. Supp. 2d 309, 312 n.3 (S.D.N.Y. 2000).

¹⁰⁰ For other wonderful examples of questions that could only arise in the modern era, see generally Sonia Katyal, *Semiotic Disobedience*, 84 Wash. U. L. Rev. 489 (2006) (describing artist-activist groups on the web that imitate the operations of a corporation or create fake membership networks).

¹⁰¹ Cf. Grey, *supra* note 25, at 39 (noting that Langdell's formalism was "not readily adapted to a period of rapid social change . . . during the early years of the twentieth century").

¹⁰² See *Burlington Indus. Inc. v. Ellerth*, 524 U.S. 742, 751-61 (1998) (describing the development of direct and vicarious employer liability standards by courts interpreting Title VII).

¹⁰³ See *id.* at 765.

¹⁰⁴ Cf. Pound, *supra* note 2, at 606 (arguing that "[p]erfection of scientific system and exposition tends to cut off individual initiative in the future, to stifle independent consideration of new problems and of new phases of old problems, and to impose the ideas of one generation upon another").

¹⁰⁵ For examples, see FELDMAN, *supra* note 1; see also works cited *supra* note 1 (describing failed attempts to use science to

¶93 Although I have described law as constantly driven to adapt towards change, I do not intend to suggest that science is unchanging or that nature, as the subject of science, is unchanging. Nature may evolve. More importantly, our ability to manipulate nature may evolve. Science is not merely about gaining an understanding of nature—seeking explanations to satisfy wonder.¹⁰⁶ Much of science is dedicated to manipulating nature, whether the subject is resisting cancer or resisting gravity. Although the enterprise of science assumes there are fundamental elements of the physical world that we try to understand, the purpose of our understanding may be to bend nature towards our will.

¶94 Thus, one could argue that there is nothing unique about the evolutionary character of law. Science changes and even nature, the topic of study in science, itself evolves. Nature, in limited circumstances, may even evolve specifically to avoid our scientific efforts. Bacteria can develop resistance to the medications we introduce, and cancer cells may find other pathways for growth as scientists block existing ones.

¶95 The question is not whether things change. The question is whether the way in which *law* changes makes science a bad fit for integration into legal doctrines. We follow the same failed paths again and again because we blind ourselves to the nature of law and to the limitations of what science can do for it.

¶96 While the issue is not whether science is similar to law, the issue also is not whether science is different from law. Hardly any modern scholar would argue with the observation that science is different from law, at least on the level of a broad generalization. For example, if one asks whether law's questions are testable, in the sense that that they are capable of being tested, the answer would have to be no. This is certainly true at a simplistic concrete level. As a society, we would never tolerate true experimentation in law. Law has an immediate responsibility to individuals, and it would be difficult to imagine judges saying "let's convict this guy and see how well it works out" or "let's hold this company liable and see how well it works out." We think of the legal system as testing out theories, improving upon them, and discarding those that work less well. The process may be evolutionary to some degree, in the sense that those things that work tend to remain and those that are clear failures tend to be discarded, but it is not experimental in the precise way that scientists would consider valid.

¶97 Legal academics can engage in some variants of experimentation, or at least forms of data analysis. They are working in the abstract, however, several layers removed from what can actually be tested, let alone what can be determined to have predictive capacity. They also must work with the unhappy constraint of having to deal with all those messy variables that cloud our ability to know whether the results we think we find are related to any reliable degree to our interpretation of them.

¶98 Using science as the basis for legal rules is a little like saying, "if you want to race a horse at maximum speed, first release its hand brake and pull away from the curb." One can make useful analogies between the two modes of transportation, but they are simply different beasts.

¶99 The comparison of science and law isn't a matter of being inferior or superior. Such concepts make little sense when one is comparing things in different contexts. Champagne is inferior to rubbing alcohol in alcoholic content, for example, but that is unlikely to matter much on New Year's Eve.¹⁰⁷ Our failure to understand nuances in the intersection of law and science plays out in the unsuccessful choices we make as we reach for what we perceive to be superior.

¶100 Those who are more abstractly inclined also could ask whether law could ever exist outside of our perception of it. Science as an enterprise may be seriously flawed, but it presupposes the existence of an enduring nature which we can attempt to quantify and explain. There is an objective reality in nature, even if the human perceiver is clouded in subjectivity. One could analogize to history as well. An event exists even if our ability to interpret it is affected by whether we have

resolve difficult legal issues in doctrines related to abortion, copyright, gene patents, environmental regulation, antitrust, child custody, school desegregation, negligence, and public utility regulation).

¹⁰⁶ See ROSENBERG, *supra* note 8, at 22 (paraphrasing Aristotle).

¹⁰⁷ See Machlup, *supra* note 54, at 151 (listing provocative comparisons of inferiority and superiority in the context of challenging whether social sciences are inferior to natural sciences).

printing presses, TV video cameras, or webcams with desktop editing capabilities. Our ability to interpret the event will be further affected by the theories and philosophies which we bring to our interpretation. The existence of the event remains fixed, however, even if our understanding of the event may change across time.

- ¶101 One need not answer the metaphysical question of whether absolute concepts of law and justice exist outside of whatever structures we create or interpretations we impose, as interesting as that question may be. The problem is our desire for enduring structures in law and the consequences that result when we reach for what we perceive as enduring outside of law.

V. CONCLUSION

- ¶102 Problems at the intersection of law and science are exacerbated by our misunderstanding of the nature of science and of what science can do for law. We see science as a pillar of certainty and hope that by importing science into law, we can create the enduring, reliable frameworks that we crave.

- ¶103 That, however, is neither the nature of science nor the nature of law. Science is not a purveyor of certainty but a rough approximation of the best we can imagine at a given moment in time. Even if science could offer certainty, importing science could not bring certainty to law, given the nature of law. Both human nature and the structure of legal discourse constantly drive law into the new and undecided. When the legal system borrows from science, the process of evolution and adaptation breaks down.

- ¶104 Those engaged in the modern scientific enterprise have come to understand the remarkable limitations in the enterprise of science and even in our ability to define what constitutes science. Law, however, is still stuck in a pre-twentieth century vision of science. This disconnect leads us to misunderstand what science can do for law and exacerbates problems at the interface of law and science. It is time we expand our understanding.