JBTS
Journal of Biblical and Theological Studies
VOLUME 2 | ISSUE 2

Christianity and the Philosophy of Science

[JBTS 2.2 (2017): 180-207]

Christian Theology of Creation and the Metaphysical Foundations of Science

Joshua M. Moritz

Joshua Moritz is an adjunct professor of philosophy at the University of San Francisco, Lecturer of Philosophical Theology and Natural Sciences at the Graduate Theological Union in Berkeley, and Academic Editor of the journal *Theology and Science*.

Abstract: Recent scholarship within the history and philosophy of science has shown that in both the past and the present, specifically Judeo-Christian theological assumptions about the value, the intelligibility, the regularity, and the character of the cosmos have provided foundational assumptions for certain key scientists and scientific discoveries. This article investigates the nature of the interaction between science and Christian theology by exploring the role that metaphysical presuppositions and theological concepts have played—and continue to play—within the scientific process. I will examine the role of Christian theological thought within both the general philosophical presuppositions that undergird the whole scientific enterprise and within particular presuppositions that were present during pivotal episodes of scientific discovery. I will show how Christian theology has both implicitly and explicitly influenced (and still influences) the ethical values, aesthetic principles, philosophical commitments, metaphysical presuppositions, and motivations underlying the modern scientific project. Because such non-empirical shaping principles are a key part of what science *is*, science really does need faith.

Keywords: Metaphysical Presuppositions of Science, Role of theology in science, intelligibility of cosmos, contingency of cosmos, values in science, Ockham's Razor

Beginning in the late twentieth century, philosophers and historians of science have increasingly discovered that the practice of science cannot be neatly separated from its social and cultural context. Historians of science have identified that a key dimension of the social context of science are numerous "ways in which religious beliefs have influenced science."[1] These ways include "presuppositions underwriting science . . . sanctions and motives for doing science . . . principles for regulating scientific methodology and for selecting acceptable theories," and so on.[2] Moreover, recent

1. John Hedley Brooke, *Science and Religion: Some Historical Perspectives* (Cambridge: Cambridge University Press, 1991), 18-33

2. Edward B. Davis, "Christianity and Early Modern Science: The Foster Thesis Reconsidered," in *Evangelicals and Science in Historical Perspective*, eds. David N. Livingstone, D.G. Hart, and Mark A. Noll (Oxford: Oxford University Press, 1999), 77.

scholarship within the history and philosophy of science has shown that in both the past and the present, specifically Judeo-Christian theological assumptions about the value, the intelligibility, the regularity, and the character of the cosmos have provided "foundational assumptions for certain key scientists and scientific discoveries."[3] Scholars in this area have found that Christian theological beliefs have had "both internal and external influences on the development of science."[4] In this article I will explore the nature of the interaction of science and theology by investigating the role that metaphysical presuppositions and Christian theological concepts play within the scientific process.[5] I will show how Christian understandings of creation have provided a conceptual and theoretical foundation for values and shaping principles within science, for general philosophical presuppositions that undergird the whole scientific enterprise, and for numerous particular presuppositions that were present during pivotal episodes of scientific discovery.

The General Presuppositions of Science

The scientific enterprise is founded upon a number of *general presuppositions* about the nature of reality. These presuppositions are non-empirical philosophical beliefs about things such as the orderliness and regularity of reality, the ontological *objectivity* of reality, the intelligibility and contingency of existent structures and entities, the agential passivity of non-conscious nature, the unity and uniformity of the physical universe, and so on. These presuppositions are *general* in that they necessarily precede and underpin *all* scientific experimentation and reasoning. And these general presuppositions are *a priori* "conditions that are necessary for the possibility of scientific activity as such, although they can be ignored by particular scientists."[6] As *preconditions* they are absolutely required for science to take place and are not open to experimental confirmation or falsification by scientific experimentation. The nature of these general presuppositions is such that "for science to develop, these beliefs must be held, at least implicitly, by society as a whole and by scientists themselves."[7]

3. Alan G. Padgett, "Science and Theology," in *The Encyclopedia of Christianity*, vol. 4, ed. Erwin Fahlbusch, et al. (Grand Rapids: Eerdmans/Brill, 2005), 873.

4. Peter E. Hodgson, *Theology and Modern Physics* (Burlington, VT: Ashgate, 2005), 16. See also Peter E. Hodgson, "Presuppositions and Limits of Science," in *The Structure and Development of Science,* eds. G. Radnitzky and G. Andersson (Dordrecht: Reidel, 1979), 133-46.

5. Following Stephen J. Wykstra who says, "Our vision of the nature of science needs to be broadened if we are to account for the roles that metaphysical and religious believing play within the scientific process." Stephen J. Wykstra, "Religious Beliefs, Metaphysical Beliefs, and Historiography of Science," *Osiris,* Vol. 16, *Science in Theistic Contexts: Cognitive Dimensions* (Chicago: University of Chicago Press, 2001), 29-46, 29.

6. Mariano Artigas, "Three Levels of Interaction Between Science and Philosophy," in *Intelligibility in Science*, ed. C. Dilworth (Amsterdam: Rodopi, 1992), 123.

7. Hodgson, *Theology and Modern Physics*, 16. See also Peter E. Hodgson, "Presuppositions and Limits of Science," 133-46.

Aesthetic, Epistemic, and Moral Values That Shape Science

1. The Aesthetic Value of Simplicity

The belief that simple theories are better than more complex theories is a foundational aesthetic value that guides the practice of science and it is one of the most important philosophical assumptions undergirding the belief in the explanatory power of scientific reductionism. The idea of explanatory simplicity was first introduced by Aristotle (384-322 BCE) as a principle of parsimony which affirms that the simplest explanation for a given phenomenon is the one that will most likely be true. Aristotle states this notion as a fundamental assumption. He says, "We may assume the superiority *ceteris paribus* of the demonstration which derives from fewer postulates or hypotheses."[8] One should thus favor simpler theories and explanations over those that are more complex. Over a thousand years later, we find this philosophical principle affirmed in the theology of Thomas Aquinas (1225-1274): "If a thing can be done adequately by means of one, it is superfluous to do it by means of several; for we observe that nature does not employ two instruments where one suffices."[9] This approach to logic came to be called "Ockham's Razor," after the logician and Franciscan friar William of Ockham (1287-1347) who taught that explanatory entities should not be multiplied beyond necessity.

Emerging as a crucial logical axiom in the Christian theology of the Middle Ages Ockham's Razor was an important guiding principle in shaping the foundation of early modern science. When Galileo compares the "Two Chief World Systems" that explain the motions of the planets (which at the time would have been that of Copernicus and that of Tycho Brahe) he assumes that there can be only *one* model of the solar system that is correct. This is because, Galileo explains, "Nature does not multiply things unnecessarily; that she makes use of the easiest and simplest means for producing her effects; that she does nothing in vain, and the like."[10] Later in the seventeenth century the well-known physicist Isaac Newton (1643-1727) includes Ockham's Razor as one of his three "rules of reasoning in philosophy" in his *Principia Mathematica*: "Rule I: We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances."[11] Writing a few generations after Newton, the chemist Antoine Lavoisier (1743-1794) affirms that "It is, after all, a principle of logic not to multiply entities unnecessarily," and he applies this principle dutifully in his practice of science as he argues against hypothetical substances, such as phlogiston, as gratuitous suppositions. "If all of chemistry can be

8. Aristotle, *Posterior Analytics*, trans. Richard McKeon (Oxford: Clarendon Press, 1963), 150.

9. Thomas Aquinas, *Basic Writings of St. Thomas Aquinas*, trans. A. C. Pegis (New York: Random House 1945), 129.

10. Galileo Galilei, *Dialogue Concerning the Two Chief World Systems*, trans. Stillman Drake (Berkeley: University of California Press, 1962), 397.

11. Isaac Newton, *Principia Mathematica* (London, 1687), 41:1.

explained in a satisfactory manner without the help of phlogiston," says Lavoisier, "that is enough to render it infinitely likely that the principle does not exist, that it is a hypothetical substance, a gratuitous supposition."[12] Writing more than 200 years later, Albert Einstein, agrees: "The grand aim of all science . . . is to cover the greatest possible number of empirical facts by logical deductions from the smallest possible number of hypotheses or axioms."[13]

Today the philosophical centrality of Ockham's Razor remains and "many scientists believe that simplicity is a crucial element in their quest for knowledge."[14] The vast majority of current practicing scientists believe that, all things being equal, simpler theories are better.[15] Philosopher of biology Elliot Sober explains that "scientists . . . frequently appeal to parsimony to justify their choice of hypotheses" and that "removing the principle of parsimony from the organon of scientific method threatens to deprive science of its results"[16]

But why should scientists favor simpler theories over more complex ones? There is no *simple* answer to this question. "A problem with Occam's razor is that nearly everybody seems to accept it, but few are able to define its exact meaning and to make it operational in a non-arbitrary way."[17] There is no obvious logical or empirical connection between plausibility and parsimony. As philosopher of science Ernan McMullin says, "Efforts to express a criterion of 'simplicity' in purely formal terms continue to be made, but have not been especially successful."[18] Although the connection between simplicity and truth is taken for granted by many practicing scientists, "There is no reason—in the absence of *independent* belief in the simplicity of nature," says philosopher of science James McAllister, "why that policy should result in hypotheses that are true more often than would any other."[19] Sober points out that it is "only because of a set of *background assumptions*" that parsimony is allowed to connect with plausibility within a particular research problem. However, says Sober, "what makes parsimony reasonable in one context…may have nothing

12. Antoine-Laurent de Lavoisier, "Réflexions sur le Phlogistique," in *Oeuvres: Volume 2* (Paris: Imprimerie Impériale, 1862*),* 623-24.

13. Albert Einstein, quoted in Leonard Kollender Nash, *The Nature of the Natural Sciences* (Boston: Little, Brown, 1963), 173.

14. Hugo A. Keuzenkamp, Michael McAleer, and Arnold Zellner, "The enigma of simplicity," in *Simplicity, Inference and Modelling: Keeping it Sophisticatedly Simple,* eds. Arnold Zellner, Hugo A. Keuzenkamp and Michael McAleer (Cambridge: Cambridge University Press, 2004), 1.

15. Alan Baker, "Simplicity," *The Stanford Encyclopedia of Philosophy* (Fall 2013), ed. Edward N. Zalta, https://plato.stanford.edu/archives/fall2013/entries/simplicity/.

16. Elliott Sober, *From a Biological Point of View: Essays in Evolutionary Philosophy* (New York: Cambridge University Press, 1994), 140.

17. Hugo Keuzenkamp, Michael McAleer, and Arnold Zellner, "The enigma of simplicity," in *Simplicity, Inference and Modelling: Keeping it Sophisticatedly Simple,* eds. Hugo Keuzenkamp, Michael McAleer and. Arnold Zellner (Cambridge: Cambridge University Press, 2001), 1.

18. Ernan McMullin, "Values in Science," *PSA: Proceedings of the Biennial Meeting of the Philosophy of Science Association* 2 (1982), 3-28, 16.

19. James W. Mcallister, "Truth and beauty in scientific reason," *Synthese* 78 (1989): 25-51, 32.

in common with why it matters in another. The philosopher's mistake is to think that there is a single global principle that spans diverse scientific subject matters."[20] In the end, it would seem that Ockham's Razor is essentially an *aesthetic* value. Yet, *as* an *aesthetic* value it has played and continues to play a vital role in scientific explanation and theory choice.

2. The Aesthetic Value of Beauty

Another example of an aesthetic value within science is *beauty* itself. For the working scientist "beauty is thought (and felt) to lie in explaining much with little, and in finding pattern, especially simple pattern, in the midst of apparent complexity and disorder."[21] Within the physical sciences beauty is often held as a guide to truth. According to McAllister, "the history of science teems with instances in which indicators of beauty appear to have prevailed over empirical criteria in directing theory-formulation."[22] And in physics today, the appeal to beauty remains as central aspect of research motivation and theory choice. Most of the great innovators in contemporary physics and cosmology have been "strongly attracted by intellectual beauty and have combined this with faith that beauty will point the path to comprehension."[23] Historian of Science Thomas Kuhn points out that such mathematical beauty was so central to the Copernican astronomer Johannes Kepler that his "entire astronomical program is based in a metaphysical faith in mathematically expressed harmonies in nature."[24] A few centuries later, Einstein affirms that for physicists "the only physical theories that we are willing to accept are the beautiful ones."[25] Indeed, Einstein was resolutely skeptical of certain aspects of quantum physics because these parts of the theory were, in his assessment, not beautiful enough to be true. For instance, his "rejection of indeterminism was essentially aesthetic: for him the harmony of the universe would be marred if, to use his own metaphor, God cast dice."[26] Nobel Prize

20. Sober, *From a Biological Point of View*, 140.

21. Herbert A. Simon, "Science seeks parsimony, not simplicity: searching for pattern in phenomena," in *Simplicity, Inference and Modelling: Keeping it Sophisticatedly Simple,* eds. Arnold Zellner, Hugo A. Keuzenkamp and Michael McAleer, (Cambridge: Cambridge University Press, 2004), 33.

22. James W. Mcallister, "Truth and beauty in scientific reason," *Synthese* 78 (1989): 25-51, 29. "In the history of science there exist many instances of theory-choice which cannot be explained without reference to these aesthetic criteria" (Mcallister, "Truth and beauty in scientific reason," 31).

23. Harold Osborne, "Mathematical Beauty and Physical Science," *British Journal of Aesthetics* 24 (1984): 291-300, 291; "Historically, this faith was actually vindicated to a great extent in the works of these scientists. Theories which they created on what were considered primarily aesthetic grounds were later confirmed experimentally." Gideon Engler, "Aesthetics in Science and in Art," *British Journal of Aesthetics* 30 (1990): 24–34, 24.

24. Roger Trigg, *Rationality and Science: Can Science Explain Everything?* (Oxford: Blackwell, 1993), 224.

25. Albert Einstein, quoted in Graham Farmelo, *It Must be Beautiful: Great Equations of Modern Science* (London: Granta Books, 2002), xii.

26. Mcallister, "Truth and beauty in scientific reason," 36.

winning atomic physicist Paul Dirac became convinced of the truth of Einstein's General Theory of Relativity primarily because of the beauty of the theory: "One has a great confidence in the theory arising from its great beauty, quite independent of its detailed successes. . . . One has an overpowering belief that its foundations must be correct quite in dependent of its agreement with observation."[27]

Despite Einstein's resistance to embrace indeterminism, the founders of quantum physics were seeking beauty in their theorizing and others saw beauty in quantum theory. One of the founders of quantum theory, Werner Heisenberg, once commented to Einstein: "I frankly admit that I am strongly attracted by the simplicity and beauty of the mathematical schemes which nature presents us."[28] Reflecting on Erwin Schrodinger's wave equation describing quantum phenomena, Dirac said: "It seems that if one is working from the point of view of getting beauty in one's equations, one is on a sure line of progress."[29] This is because, explains Dirac, "Schrodinger got this equation by pure thought, looking for some beautiful generalization of De Broglie's ideas, and not by keeping close to the experimental development of the subject in the way Heisenberg did."[30] Dirac even goes so far as to say that if one wishes to discover truth in physics, "it is more important to have beauty in one's equations than to have them fit experiment."[31]

The idea that beauty is a guide to truth remains important among current physicists as well.[32] Contemporary physical science "is infused with a powerful element of aesthetic faith. . . . It is a faith that aesthetically good theory will be confirmed by fact and experience because the universe itself is aesthetically structured."[33] For example, the physicist Steven Weinberg has recently reflected, "It is precisely in the application of pure mathematics to physics that the effectiveness of aesthetic judgments is most amazing. . . . Mathematical structures that confessedly are developed by mathematicians because they seek a sort of beauty are often found later to be extraordinarily valuable by physicists."[34] Weinberg explains that "time and

27. James W. Mcallister, "Is Beauty a Sign of Truth in Scientific Theories?" *American Scientist* 86 (1998): 174-183, 174.

28. Werner Heisenberg, "Letter to Albert Einstein," in Ian Stewart, *Why Beauty is Truth: A History of Symmetry* (New York: Basic Books, 2008), 278.

29. Paul Dirac, "The Evolution of the Physicist's Picture of Nature," *Scientific American* 208:5 (1963): 45-53, 47.

30. Quoted in Mcallister, "Truth and beauty in scientific reason," 30.

31. Dirac, "The Evolution of the Physicist's Picture of Nature," 47.

32. Beauty is also important for non-physicists. James D. Watson reports that, when Rosalind Franklin learned of his and Francis Crick's model of the structure of DNA, she "accepted the fact that the structure was too pretty not to be true." J. D. Watson, *The Double Helix: A Personal Account of the Discovery of the Structure of DNA,* ed. G. S. Stent (London: Weidenfeld and Nicolson, 1968), 210; Evolutionary biologist Sean Carroll says "beauty, in science, is much more than skin-deep." Sean B. Carroll, *Endless Forms Most Beautiful: The New Science of Evo Devo* (New York: W. W. Norton & Company, 2006), 13.

33. Osborne, "Mathematical Beauty and Physical Science," 293.

34. Steven Weinberg, *Dreams of a Final Theory* (New York: Pantheon Books, 1992), 153.

again physicists have been guided by their sense of beauty not only in developing new theories but even in judging the validity of physical theories once they are developed. It seems that we are learning how to anticipate the beauty of nature at its most fundamental level. Nothing could be more encouraging than we are actually moving toward the discovery of nature's final laws."[35] The appeal to beauty is particularly prevalent among contemporary advocates of String Theory—a physical theory that is mathematically elegant but may never be empirically testable. Describing the early formulation of String Theory, John Schwarz reflects, "We felt strongly that string theory was too beautiful a mathematical structure to be completely irrelevant to nature."[36] Nobel Laureate and string theorist David Gross similarly remarks that "string theory could not be wrong because its beautiful mathematics could not be accidental."[37] Mathematical and theoretical physicist Edward Witten believes that string theory must be true because of "its wonder, its incredible consistency, remarkable elegance and beauty."[38]

But why should physicists assume that beauty points to truth? Although "much tribute has been paid" to the nature of beauty in the sciences, comments philosopher of aesthetics Harold Osborne, a "systematic analysis has not been attempted but . . . it is taken for granted that anyone with a talent for scientific matters will recognize a beautiful theory when he sees it."[39] There is no purely empirical reason or justification for affirming this aesthetic criterion and, as Nobel laureate Eugene Wigner remarks, the reason for the effectiveness of mathematical beauty in physics "is something bordering on the mysterious and there is no rational explanation for it."[40] While some are comfortable seeing the role of beauty within science as a mystery, others have asserted an explicitly *theological* justification for why physicists focus on beauty. Heisenberg says that expressions of beauty such as the "miracle of symmetry," harmony, and "the beauty of simplicity" reveal the "inner truth" of physical reality because they are reflections of "the original archetype of creation."[41] Dirac similarly affirms a divine origin for such beauty: "God used beautiful mathematics in creating

35. Ibid., 90.

36. John Schwarz, "Superstring-A Brief History," in *History of Original Ideas and Basic Discoveries in Particle Physics,* eds. H. Newman and T. Ypsilantis (New York: Plenum Press, 1996), 695-706, 698.

37. Leonard Susskind, "Quark Confinement," *The Rise of the Standard Model: Particle physics in the 1960s and 1970s*, eds. Lillian Hoddeson, L. Brown, M. Riordan, and M. Dresden (Cambridge: Cambridge University Press, 1997), 233-43, 235.

38. John Horgan, "Physics Titan Edward Witten Still Thinks String Theory Is 'On the Right Track,'" *Scientific American* (September 29, 2014), https://blogs.scientificamerican.com/cross-check/physics-titan-still-thinks-string-theory-is-on-the-right-track/.

39. Osborne, "Mathematical Beauty and Physical Science," 292.

40. Eugene Wigner, "The Unreasonable Effectiveness of Mathematics in the Natural Sciences," *Communications in Pure and Applied Mathematics* 13:1 (February 1960): 1-14.

41. Engler, "Aesthetics in Science and in Art," 25.

the world."[42] Contemporary string theorists have likewise grounded the equating of truth and beauty within the Divine. Theoretical physicist Michio Kaku reflects that in string theory "the mind of God is music resonating through 11-dimensional hyperspace,"[43] and Harvard string theorist Lubos Motl comments that "Superstring/M-theory is the language in which God wrote the world."[44]

3. Epistemic and Ethical Values

In addition to aesthetic principles, which shape both the practice and content of science, there is also a central role for epistemic and ethical values within science. Since the 1960s historians and philosophers of science have increasingly recognized that science is *value-laden*—that values are an intrinsic component within scientific theorizing and scientific practice. As *assumptions* about the worth or goodness of something, values, as such, are not empirically testable. Even though popularizers of science have continued to promote the image of science as a value-free enterprise, philosophers of science have come to recognize that "value-free science is an unattainable or untenable ideal."[45]

McMullin explains that "there are certain characteristic *epistemic* values which are integral to the entire process of assessment in science."[46] The desire to have a value-free science is itself an epistemic value. *Objectivity* is likewise an epistemic value. "To call a thing objective implies that it has a certain importance to us and that we approve of it."[47] Another epistemic value, "namely truth itself, has always been recognized as permeating science."[48] In the classic account of science, says McMullin, truth was "the goal of the entire enterprise" and in the practice of science today "truth is still a sort of horizon-concept or ideal of the scientific enterprise, even though we may not be able to assert truth in a definitive manner."[49] In addition to objectivity and truth, McMullin lists the epistemic values of *unifying power* (a theory's ability to bring together previously disparate areas of inquiry), *external consistency* (a theory's consistency with other theories and with the general background of expectation),

42. John Polkinghorne, *The Particle Play* (New York: W. H. Freeman, 1979), 2 and 126.

43. Michio Kaku, "Interview on the Leonard Lopate Show," WNYC (January 2, 2004).

44. Quoted by Bert Schroer, "String theory, the crisis in particle physics and the ascent of metaphoric arguments," *International Journal of Modern Physics D Int. J. Mod. Phys. D*, 17, 2373 (14 Mar 2006): 21, http://arxiv.org/abs/physics/0603112.

45. Heather Douglas, "Rejecting the Ideal of Value-Free Science," in *Value-free science?: Ideals and Illusions*, eds. Harold Kincaid, John Dupré, Alison Wylie (Oxford: Oxford University Press, 2007), 121.

46. McMullin, "Values in Science," 6.

47. Julian Reiss and Jan Sprenger, "Scientific Objectivity", *The Stanford Encyclopedia of Philosophy* (Summer 2016 Edition), ed. Edward N. Zalta, https://plato.stanford.edu/archives/sum2016/entries/scientific-objectivity/

48. McMullin, "Values in Science," 6.

49. Ibid., 7.

internal coherence (that there should be no logical inconsistencies and no unexplained coincidences within a theory), *fertility* (a theory's ability to make novel predictions that were not part of the set of original explananda) and predictive accuracy.[50]

There are also a number of moral values that guide and shape the workings of science. For instance honesty, openness, and integrity are "moral values which have always been seen as essential to the success of communal inquiry." Science is a communal enterprise that "cannot succeed unless results are honestly reported, unless every reasonable precaution be taken to avoid experimental error, unless evidence running counter to one's own view is fairly handled."[51] For science to make progress, scientists need to trust that the experimental results of other scientists are genuine and not falsified.[52] Moral principles shape science via ethical guidelines for conducting research on human and animal subjects, cultural norms and social values that determine the appropriateness of research topics (e.g., conservation biology, nuclear weapons research, genetic enhancement research), and the values of individual researchers.[53] Scientists' "personal beliefs may significantly influence the type of research problems that scientists may choose to work on, the approach that they use in addressing the problem, and the magnitude of effort and dedication that they invest in finding the solution to their chosen problem."[54] As chemist and philosopher Michael Polanyi pointed out, "Only a tiny fraction of all knowable facts are of interest to scientists, and scientific passion serves also as a guide in the assessment of what is of higher and what is of lesser interest. . . . This appreciation depends ultimately on a sense of intellectual beauty."[55]

The *practice* of science is likewise oriented towards outcomes that are ethically discerned and derived. The scientific endeavor to produce a vaccine is for the good of public health and for the good of humanity as a whole. The motivation behind investigating ecosystems is not typically for the sake of accumulating pure value-free

50. Ibid., 15-16; Thomas Kuhn similarly distinguished key epistemic values of the scientific enterprise such as accuracy, consistency, scope, simplicity, and fruitfulness (fecundity). See Thomas Kuhn. "Objectivity, Value Judgment, and Theory Choice," in *The Essential Tension: Selected Studies in Scientific Tradition and Change* (Chicago: University of Chicago Press, 1977), 321-22.

51. Mcmullin, "Values in Science," 7.

52. Hodgson, *Theology and Modern Physics,* 20. Regarding the justification of this presupposition see Meredith Wadman, "One in Three Scientists Confesses to Having Sinned," *Nature* 435, no. 7043 (June 9, 2005): 718-19. Wadman says that such "misconduct ranges from faking results outright to dropping suspect data points" (ibid.).

53. Steven Shapin and Simon Schaffer, *Leviathan and the Air Pump* (Princeton, NJ: Princeton University Press, 1985). Other types of presuppositions enter into science as well. For example philosopher Michael Stenmark explains, "Scientific knowledge presupposes introspective knowledge and knowledge based on memory, then one first must know these things to be able to do science" (Stenmark, *Scientism: Science, Ethics and Religion,* 119).

54. I. S. Caleon, G. Lopez Wui, and H.P Regaya, "Personal Beliefs as Key Drivers in Identifying and Solving Seminal Problems: Lessons from Faraday, Maxwell, Kepler and Newton," *Science Education International* 26:1 (2015): 3-23.

55. Michael Polanyi, *Personal Knowledge*: *Towards a Post-Critical Philosophy* (London: Routledge, 1962), 143.

knowledge, but rather in order to support efforts to conserve such ecosystems for the sake of the animals who live in them and the humans that enjoy them. "We are interested in scientific investigations that have consequences for action."[56] Science is pursued and funded according to the *relevance* of its findings in so far as they shed light on the things we most value. In this way, says Dupre, "fact and value are typically inextricably linked in the matters that concern us."[57]

The process of "scientific inference is regulated by normative rules" and these rules depend on diverse values. "Scientists try to construct *good* tests of their hypotheses, they judge some explanations *good* and others *bad*, and they say that some inferences are *flawed* or *weak* and others are *strong*." The italicized words in the previous sentence indicate "that scientists are immersed in tasks of evaluation. They impose their norms on the ideational entities they construct."[58] Values enter into the process of science at a number of levels—inspiration, motivation, theory construction, and theory justification. As Kuhn explains, "The criteria of [theory] choice function not as rules, which determine choice, but as values which influence it. Two men deeply committed to the same values may nevertheless, in particular situations, make different choices, as in fact they do."[59] Consequently, both epistemic and nonepistemic "values are logically needed for reasoning in science, even in the internal stages of the process."[60] Moreover, the presence of values within science is not a *bad* thing. In fact, science *should* have values. As philosopher of science Heather Douglas argues, a *value-free ideal* is a *bad ideal* for *science.* "In many areas of science, particularly areas used to inform public policy decisions, science should not be value free. . . . In these areas of science, value-free science is neither an ideal nor an illusion. It is unacceptable science."[61]

Metaphysical Presuppositions of Science

In addition to the moral values and aesthetic principles that shape science and guide scientific discovery and theory choice, there are also general metaphysical presuppositions that serve as the deeper philosophical foundations of the entire scientific enterprise. Metaphysical presuppositions that provide the necessary conditions for science include:

56. Dupre, "Fact and Value," 30.

57. Ibid., 35.

58. Ibid., 110.

59. Thomas Kuhn, *The Essential Tension: Selected Studies in Scientific Tradition and Change* (Chicago: University of Chicago Press, 1977), 331.

60. Douglas, "Rejecting the Ideal of Value-Free Science," 121.

61. Ibid.

1. A Belief that the Physical Universe is, in Some Sense Good, and therefore Worthy of Careful Study

This first necessary condition for the existence of science affirms that one must consider the objects and goals of science as *valuable* and *worth* pursuing before one pursues the study and practice of science.[62] Biologist and Nobel Laureate Konrad Lorenz expresses the goodness and worth of physical reality in the language of love, and says that he and "all of the biologists [he] know[s] are undeniably lovers of their objects of study."[63] The presupposition of goodness or worth with regard to physical reality is often related to and conveyed by the appreciation aesthetic values such as awe, wonder, and beauty. Numerous scientists have thus affirmed that nature is *worth* studying because it is beautiful and because the study of nature fills one with awe. For instance, Heisenberg, reflecting on the process of scientific discovery in physics, says "What these internal relations show in all their mathematic abstraction, an incredible degree of simplicity, is a gift that we can only accept with humility. Not even Plato could have believed that it would be so beautiful."[64] Physicist Richard Feynman likewise expresses the goodness or worth of investigating physical reality through invoking the aesthetic values of awe and wonder:

> The same thrill, the same awe and mystery, come again and again when we look at any problem deeply enough. With more knowledge comes deeper, more wonderful mystery, luring one on to penetrate deeper still. Never concerned that the answer may prove disappointing, but with pleasure and confidence we turn over each new stone to find unimagined strangeness leading on to more wonderful questions and mysteries.[65]

2. A Belief that the World is Orderly and Rational

If physical reality were assumed to be unstructured, disorderly, or fundamentally chaotic, science would be impossible.[66] The presupposition that order exists in nature is thus a necessary condition of scientific inquiry because if one did not believe that order existed at all in nature, then searching for it scientifically would be pointless.[67] For example, Einstein's development of the general theory of relativity was premised on the assumption that the universe is a puzzle to be solved, and his lifelong search for a unified field theory (to unify general relativity with electromagnetism) assumed

62. Peter Hodgson, "Presuppositions and Limits of Science," 136.

63. Marco Bersanelli Mario Gargantini, *Galileo to Gell-Mann: The Wonder that Inspired the Greatest Scientists of all Time* (Philadelphia: Templeton Press, 2009), 10.

64. Ibid., 6.

65. Quoted in ibid., 7.

66. Trigg, *Rationality and Science*, 224.

67. Mariano Artigas, *The Mind of the Universe: Understanding Science and Religion* (London: Templeton Foundation, 2000), 44.

that there is a deeper cosmic rationality waiting to be discovered. As physicist Paul Davies comments,

> All science proceeds on the assumption that nature is ordered in a rational and intelligible way. You couldn't be a scientist if you thought the universe was a meaningless jumble of odds and ends haphazardly juxtaposed. When physicists probe to a deeper level of subatomic structure, or astronomers extend the reach of their instruments, they expect to encounter additional elegant mathematical order. And so far this faith has been justified.[68]

3. A Belief that the Order of the World is Open to the Human Mind

Scientists assume there is an order and rationality behind the universe that science studies and at the same time they assume that the human mind is able to access and understand that rationality. According to philosopher of science Roger Trigg, "an absolute presupposition of science is the human ability to recognize what is true and reason about what could be true." This is a metaphysical presupposition because it necessarily precedes the study of the nature of the world. "Rationality and the human freedom to exercise it make scientific investigation and argument possible."[69] Without a firm conviction that "the form of things is intelligible, and therefore definable," there would be no point in embarking on the scientific quest to make sense of the world.[70] One would not scientifically seek to understand the world unless one already believed that the world could be understood. As physicist and theologian John Polkinghorne elaborates,

> We are so familiar with the fact that we can understand the world that most of the time we take it for granted. It is what makes science possible. Yet it could have been otherwise. The universe might have been a disorderly chaos rather than an orderly cosmos. Or it might have had a rationality which was inaccessible to us. . . . There is a congruence between our minds and the universe, between the rationality experienced within and the rationality observed without. This extends not only to the mathematical articulation of fundamental theory but also to all those tacit acts of judgment, exercised with intuitive skill, which are equally indispensable to the scientific endeavour.[71]

Physicist James Gates explains that in order to do science "one has to have a kind of faith that the universe is understandable." Science, says Gates, "is in fact a

68. Paul Davies, "Taking Science on Faith," *The New York Times* (November 24th, 2007), 61-62.

69. Roger Trigg, *Beyond Matter: Why Science Needs Metaphysics* (West Conshohocken: Templeton, 2015), 71.

70. Michael Foster, "The Christian Doctrine of Creation and the Rise of Modern Natural Science," *Mind* 43 (1934): 446-68, 455.

71. John Polkinghorne, *Science and Creation: The Search for Understanding* (London: SPCK, 1988), 20-21.

conversation, and you have to have faith that the universe is willing to have that conversation."[72] Every new scientific research venture assumes that the order present within the universe will lend itself to being understood by the human mind. Because this assumption that the universe will "talk back" is based on faith and cannot be given a scientific explanation, many scientists have found this relationship between our minds and the universe to be surprising and mysterious. Considering this metaphysical mystery, Einstein once reflected, "the most incomprehensible thing about the Universe is that it is comprehensible."[73] Indeed, remarks Trigg, "the intelligibility and intrinsic rationality of reality cannot be taken for granted" because "this is presupposed within science and cannot be given a scientific explanation." The presumed rationality and intelligibility of the cosmos is a "metaphysical fact, and the explanation for which, if there can be one, must come from beyond science."[74]

4. A Belief that the Order of the World is Contingent Rather than Necessary

According to physicist and philosopher of science Mariano Artigas, "Science shows us an order that is both rational and contingent (that is, its laws and initial conditions were not necessary). It is the combination of contingency and intelligibility that prompts us to search for new and unexpected forms of rational order."[75] Trigg explains that "it was the constant temptation of ancient thinkers, such as Aristotle, to work out how the world had to be from first principles and to discount the need for a rigorous program of empirical observation and experiment."[76] The empirical focus of modern science contrasts with the mental and mathematical investigations of the ancient Greeks. "The genius of modern, empirical science, as compared with mere speculation about the nature of the world, is the realization that the physical world does not have to be as it is. It is contingent."[77] While *necessary* order could be discerned through pure introspective thought (like the truths of mathematics, geometry, or logic), *contingent* or dependent order can be discovered only by making experiments and through investigating what the world is really like. That which is contingent is knowable only by sense experience. There could have been a number of different ways that the universe was put together, but the only way to find out how it actually was put together is to examine it in its details and dynamics. In this way the early scientist Pierre Gassendi (1592-1655) derived from his faith in the

72. S. James Gates, "The Workings of Science," (AAAS, December 2016), http://www.science-forseminaries.org/resource/the-workings-of-science/

73. Albert Einstein, "Physics and Reality," in *Ideas and Opinions*, trans. Sonja Bargmann (New York: Bonanza, 1954), 292.

74. Trigg, *Beyond Matter*, 59.

75. Artigas, *Mind of the Universe*, 14-15.

76. Trigg, *Beyond Matter*, 76.

77. Trigg, *Beyond Matter*, 76.

contingency of the cosmos a "conviction that empirical methods are the only way to acquire knowledge about the natural world and that the matter of which all physical things are composed possesses some properties that can be known only empirically."[78] The concept of contingency "is essential to science because contingency demands an empirical method."[79] Yet, the contingency of the rational order of nature may not be investigated or established through empirical investigation. "The comprehensive presupposition upon which the whole contingent order of things reposes in order to be what it is . . . cannot be established in any way from within the rational frame of the contingent order" itself.[80]

5. A Belief in Metaphysical Realism

To engage in scientific theorizing means presupposing that there is a real world of objective physical reality and that one can, at least to some extent, obtain information about that world, which exists independently of the mind. In other words, the attempt to gain knowledge about the world must first presuppose the existence of the world and that the world is not an illusion or virtual reality. "Metaphysical realism," says philosopher of science Nicholas Rescher, is not the result of an inductive inference, but is rather "a regulative presupposition that makes science possible in the first place."[81] Metaphysical realism is "a precondition for empirical inquiry," and "a presupposition for the usability of observational data as sources of objective information."[82] In this way, says Rescher, "We do not learn or discover that there is a mind-independent physical reality, we presume or postulate it."[83] Trigg explains, "Science has to assume that it is investigating a world that has an independent existence. Otherwise it is a mere social construction reflecting the conditions of particular societies at a particular time."[84] The reality of the material world places crucial constraints on scientific theorizing, so true theories must match up with the structures and relationships already existing in nature. For science to make progress, reality as it concretely exists must be

78. Margaret J. Osler, *Divine Will and the Mechanical Philosophy: Gassendi and Descartes on Contingency and Necessity in the Created World* (Cambridge: Cambridge University Press, 1994), 1.

79. Artigas, *Mind of the Universe*, 44.

80. Thomas F. Torrance, "The Transfinite Significance of Beauty in Science and Theology," in *L'art, la science et la métaphysique: Études offertes à André Mercier*, eds. Luz García Alonso, Evanghelos Moutsopoulos, and Gerhard Seel (Berne: Peter Lang, 1993), 393-418.

81. Nicholas Rescher, *Scientific Realism: A Critical Reappraisal* (Dordrecht: Reidel, 1987), 126.

82. Nicholas Rescher, *Epistemology: An Introduction to the Theory of Knowledge* (Albany, NY: SUNY, 2003), 350.

83. Rescher, *Scientific Realism,* 126.

84. Roger Trigg, "Realism," in *Encyclopedia of Science and Religion,* ed. J. Wentzel Van Huyssteen (New York: Macmillan Reference, 2003), 714. Biologist and theologian Alister McGrath writes, "There can be little doubt that most natural scientists espouse a range of opinions which are recognizably 'realist' in their core affirmations, reflecting a common commitment to the ontological finality of the natural order. Realism works." Alister McGrath, *A Scientific Theology*, *Volume. 2, Reality* (London: T & T Clark, 2006), 123.

permitted to change one's previous abstract conceptions of that reality. This is why "scientific discoveries are often quite unexpected."[85] While scientific theories about the nature of reality can be falsified, realism itself, as a metaphysical affirmation cannot. As Trigg explains, "realism cannot be falsified, since the idea of falsification depends on notions of truth and falsity that assume that the world has an independent existence. There could otherwise be no reality to prove us wrong."[86]

6. A belief in the unity and uniformity of the physical universe.

The assumption that physical reality at some deep level is consistent, and that nature functions uniformly, is a fundamental presupposition of all scientific activity. "The idea of the general uniformity of nature," says Trigg, "underpins the conduct of science, and the alternative is to give up science. Discovering it by scientific means begs the question."[87] The "scientific method," explains philosopher of science Karl Popper, "presupposes *the immutability of natural processes*, or the 'principle of the uniformity of nature.'" For example, physicists assume that the speed of light throughout the universe (where it has not been measured) is the same as the speed of light here on Earth (where it has been measured). This principle of uniformity, says Popper, is a "metaphysical faith in the existence of regularities in our world" that necessarily underpins the scientific method as a whole.[88] According to historian of science Reijer Hooykaas "it was not experience alone but also a belief in an order as yet undiscovered—that is, in a certain uniformity of nature—which played, and still plays an important role in science."[89] The assumption that the laws of nature are the same everywhere throughout the cosmos is what allows scientists to extrapolate from presently available knowledge to distant times (e.g., the past in geology and the past and future in cosmology) and to distant parts of the cosmos (e.g., in astronomy and cosmology). Without the postulated uniformity of the cosmos scientists could not make any inductive inferences or predictions.[90] Without this faith in nature's uniformity and unity, says Popper, any practical action within science, would be "hardly conceivable."[91]

These general presuppositions about the nature of reality—the orderliness and regularity of reality, the ontological *reality* of reality, the intelligibility and contingency of existent structures and entities, and the unity and uniformity of the physical universe—necessarily precede and underpin all scientific experimentation

85. Ian Barbour, *Religion in an Age of Science* (San Francisco: Harper & Row, 1990), 44.

86. Trigg, *Beyond Matter*, 100.

87. Ibid.

88. Karl Popper, *The Logic of Scientific Discovery* (London: Unwin Hyman, 1990), 250.

89. Reijer Hooykaas, *Fact, Faith, and Fiction in the Development of Science* (Dordrecht: Kluwer, 1999), 11.

90. Ratzsch, "The Nature of Science," 49.

91. Popper, *The Logic of Scientific Discovery,* 250.

and reasoning. "For science to develop," says physicist and philosopher Peter Hodgson, "these beliefs must be held, at least implicitly, by society as a whole and by scientists themselves."[92] Modern science presupposes these beliefs "as the condition of its own possibility."[93] Such presuppositions (and others) are *a priori* "conditions that are necessary for the possibility of scientific activity as such, although they can be ignored by particular scientists."[94] As preconditions, they are absolutely required for science to take place and are not open to experimental confirmation or falsification by scientific experimentation. As Trigg explains, "empirical investigation cannot solve metaphysical issues, and if it tries to, it only goes around in circles."[95] As the necessary conditions for the possibility of science these metaphysical presuppositions, explains Artigas, "continue to be present, not as a kind of philosophical ornament, but as a real part of science itself." When we study the presuppositions of science, says Artigas, "we are studying science itself in a strict sense."[96] And such presuppositions continue to significantly impact science today. McMullin says that, while "one might be tempted to think that regulative principles of a broadly metaphysical kind no longer play a role in the natural sciences . . . even a moment of reflection about the current debates in elementary-particle theory, in quantum-field theory, and in cosmology ought to warn that this is far from the case."[97]

Theological Foundations of the General Metaphysical Presuppositions of Science

All the metaphysical presuppositions listed above, which continue to play a vital role within current science, require a certain degree of faith. Today, scientists often take these philosophical assumptions for granted and their implicit faith in them need not necessarily be considered religious. Historically, however, each of these presuppositions developed within a specific religious context and all were supported and affirmed by particular religious concepts within a particular religious culture. The specific religious context, within which early modern science developed, was the Christian faith as it emerged from Judaism and was passed down from the European

92. Hodgson, *Theology and Modern Physics*, 16. See also Hodgson, "Presuppositions and Limits of Science,"133-46.

93. Foster, "The Christian Doctrine of Creation and the Rise of Modern Natural Science," 447

94. Mariano Artigas, "Three Levels of Interaction between Science and Philosophy," in *Intelligibility in Science*, ed. C. Dilworth (Amsterdam: Rodopi, 1992), 123.

95. Trigg, *Beyond Matter*, 100.

96. Artigas, *Mind of the Universe*, 25.

97. Ernan McMullin, *Newton on Matter and Activity* (Notre Dame: University of Notre Dame Press, 1978), 127.

Middle Ages to the early modern natural philosophers who were the first "scientists."[98] Historian of science John Hedley Brooke explains, "Prominent natural philosophers of the early modern period did not distinguish what we would call the scientific aspects of their work from what we would call theology. Their study of the natural world was conceived as a study of God's creation, disclosing something of the nature of God."[99] Within this cultural matrix, a number of specifically Christian theological understandings of the natural world and the human mind encouraged the development of the foundational presuppositions of science. In other words, "Christian theology provided several of the beliefs on which science is based."[100]

Physicist, philosopher, and theologian, Ian G. Barbour explains that a number of key metaphysical presuppositions of science are grounded in "the basic *theological affirmations* in the first chapter of Genesis." Among them are the convictions that "the world is essentially good, orderly, coherent, and intelligible," that "the world is dependent on God" and thus contingent because "God is sovereign, free, transcendent, and characterized by purpose and will." Barbour points out that "these are all assertions about characteristics of God and the world in every moment of time, not statements about an event in the past. They express ontological rather than temporal relationships."[101] Artigas explains how these presuppositions became deeply embedded within the intellectual milieu that gave rise to science:

98. In speaking of the philosophical presuppositions that emerge from the *Christian,* rather than the so-called "Judeo-Christian", doctrine of creation, I do not intend to exclude *Jewish* understandings of creation which often employ the same or similar concepts. I am merely contextualizing the discussion in order to avoid a lengthy digression regarding what, in fact, Christian and Jewish understandings of creation historically had in common. For example, not all would agree that the notion of *creatio ex nihilo* was explicitly assumed in the Hebrew thought of Genesis or in later Early Jewish conceptions. *Creatio ex nihilo* is unambiguously assumed in the earliest Christian witness, however. In a similar way, the general presuppositions about creation that emerge from Islam, Mormonism, and Process Thought have a great degree of overlap with Christian understandings. This overlap, however, is due to the historical dependence of these later metaphysical perspectives upon the Christian concepts which preceded them. Consequently general presuppositions that are likewise found in Islam may be thought of as originally and primarily Christian.

99. John Hedley Brooke, Margaret Osler and Jitse van der Meer, *Science in Theistic Contexts: Cognitive Dimensions* (Chicago: University of Chicago Press, 2001), ix. Early modern scientists referred to themselves as "natural philosophers." The "natural philosophy" which Brooke is referring should not be confused with "natural theology" of nineteenth century Deism. Deistic natural theology sought to prove the existence of God without explicit recourse to religious scriptures or reference to theological affirmations or presuppositions. However, Deistic natural philosophy and natural theology were essentially a secularized version of the Christian doctrine of creation (as opposed to being a natural religion that could be derived purely from reason). Deistic natural theology thus still implicitly relied on the philosophical presuppositions supplied by the Judeo-Christian understanding of creation. See Peter A. Byrne, *Natural Religion and the Religion of Nature: The Legacy of Deism* (London: Routledge, 1989).

100. Hodgson, *Theology and Modern Physics*, 17.

101. Ian G. Barbour, *When Science Meets Religion: Enemies, Strangers, or Partners?* (San Francisco: Harper Collins, 2013), 48.

> The development of empirical science as a self-sustaining enterprise required . . . a kind of faith in the rationality of the world and also in the human capacity to know that world. In short, empirical science is possible only if our world possesses a strong kind of order and if we are capable of investigating it. Actually, after sharing the Christian faith for several centuries, Medieval and Renaissance Europe was built on a common ground that included, as a basic tenet, the doctrine of creation with all its implications: that the world had been created by an omnipotent and wise God and that, therefore, a natural order exists; that the natural order is contingent, because God's creation is free and thus the world cannot be a necessary product of God's action; that human beings, as creatures who participate in God's nature, can reach a knowledge of that natural order; and finally that owing to the contingent character of the world, in order to reach that knowledge we must not only think, but also perform experiments that allow us to know how our world really behaves.[102]

In the late medieval and early modern periods theological convictions became embodied within philosophical presuppositions and they worked together to form many of the key conceptual underpinnings of modern science. Rather than religion acting as a stumbling block to the rise of science, religion was, in fact, a cornerstone. As historian of science Edward Grant has shown, "in the Latin Middle Ages of Western Europe an intellectual environment was established that proved conducive to the emergence of early modern science." During this formative historical period a combination of cultural attitudes, institutions such as universities, and beliefs critically coalesced into what may be called the "the foundations of modern science."[103] Consider the theological origins for each of the metaphysical presuppositions listed above:

1. The Goodness and Worth of the Physical Reality that God Created

The notion of the world's "goodness" is rooted in the foundational creation narrative of both Judaism and Christianity. In Genesis, God beholds the cosmos he created and asserts that "all that he had made" was indeed "good" (Gen 1:31). The Hebrew word translated as "good" also means "beautiful." The created world here has an intrinsic value and the creatures therein "manifest in the most varied ways the power, wisdom, and goodness of God."[104] In the early Christian understanding, nature was seen as a type of "book" authored by God, and one could come to know God through reading and studying this book. The church father Augustine (354-430) reflects, "Some people, in order to discover God, read books. But there is a great book: the very

102. Artigas, *Mind of the Universe*, 22.

103. Edward Grant, *The Nature of Natural Philosophy in the Late Middle Ages* (Washington, D.C.: Catholic University of America Press, 2010), ix.

104. Artigas, *Mind of the Universe*, 330.

appearance of created things. Look above you! Look below you! Note it; read it. God, whom you want to discover, never wrote that book with ink; instead He set before your eyes the things that He had made. Can you ask for a louder voice than that?"[105] Continuing in this Augustinian train of thought, medieval theologian Hugh of St. Victor (1096-1141) develops specific techniques for the interpretation of the "text of nature." Hugh advocates the systematic investigation of the natural world "based on the general assumption that living things can be read as signs variously of God's power, wisdom and goodness." Discerning the power of God in the immensity of the created cosmos, Hugh likewise sees God's goodness and wisdom in the elegance and beauty of creatures.[106]

The idea that the world of nature is worth studying, as it entered into the practice of early modern science, is likewise historically rooted in the Jewish and Christian Genesis text. One particularly influential passage that deeply impacted the conceptual foundations of science was Genesis 2:19-20, in which Adam names the animals according to their own identities. Adam's naming of the different creatures had long been understood as his giving names to them in accordance with their particular natures and characteristics. Jews and Christians believed humans before the Fall had a deep knowledge of nature and that it was Adam's "encyclopedic knowledge that had made possible the naming" of the various animals.[107] In the 1600s, when Francis Bacon inaugurated the modern scientific endeavor, he drew upon this understanding of Adam's knowledge of the natural world. Bacon envisioned the natural sciences as a way of "restoring, or at least repairing, the losses to knowledge that had resulted from the Fall."[108] Historian of science Peter Harrison explains, "Francis Bacon's project to reform philosophy was motivated by an attempt to determine whether the human mind 'might by any means be restored to its perfect and original condition, or if that may not be, yet reduced to a better condition than that in which it now is.'"[109] As the disobedience of the first humans caused the human mind to fall into error and lose knowledge, the scientific method was, for Bacon and other early modern practitioners of science, a technique that could work to heal the cognitive damage wrought by human sin. During the scientific revolution, says Harrison, "the methodological strictures of particular programs of natural philosophy—experimental method being perhaps the best example—were understood as applying necessary external constraints to fallen

105. Quoted in Clarence Glacken, *Traces on the Rhodian Shore: Nature and Culture in Western Thought from Ancient Times to the End of the Eighteenth Century* (Berkeley: University of California Press, 1967), 203-4.

106. Peter Harrison, *The Bible, Protestantism, and the Rise of Natural Science* (Cambridge: Cambridge University Press, 1998), 57; Hugh of St Victor, *Didascalicon*, 6.5*; De tribus diebus*, 1.

107. Peter Harrison, *The Fall of Man and the Foundations of Science* (Cambridge: Cambridge University Press, 2007), 26.

108. Ibid., 4.

109. Ibid., 1.

minds which, left to their own devices, would simply fail to accumulate any useful knowledge of the natural world."[110]

2. That God Created an Orderly and Rational Cosmos

The orderliness and rationality of the natural world were similarly assumed by early modern scientists on the basis of the Christian doctrine of creation that was part of their cultural matrix.[111] "The very idea of rationality has certain theological origins, and science as we know it arose in the context of a belief in the rational structure of reality mirroring the higher wisdom of a Creator God."[112] The concept of God's creation of all material reality out of nothing (Latin: *creatio ex nihilo*) "allowed the scientist to approach nature with the expectation that the divine rationality would be reflected in its structures and workings."[113] According to Hooykaas, "The faith in order, law, simplicity, harmony, beauty has often been connected with the faith that there is logos, reason, mind at work in the universe." The idea that the universe is deeply rational emerges from a "belief in a Mind to which the human mind has, however remotely, some resemblance, so that it is able to recognize these attributes in a creation which is the work of that Mind."[114]

Past interpretations of the history of science attributed the rationality underlying the scientific endeavor to the influence of the ancient Greeks. This idea that natural science came to the modern world as a legacy from ancient Greece, says Harrison, "continues to exercise a tenacious hold on the popular imagination and still informs many nonspecialist accounts of science and its history." However, he continues, "historians of science have now largely abandoned much of this narrative." A "significant deficiency in this common reconstruction of the history of science lies in the assumption that these ancient Greek accounts of the cosmos partake of the ethos of modern science, and that they share to a significant degree its goals and methods."[115] While the various Greek philosophical schools employed logic in their speculative understandings of the world, they did not generally see the structure of the cosmos as an expression of a rational plan that could—and should—be investigated on a more

110. Ibid., 15.

111. Though anachronistic, the word "scientists" is used here for clarity's sake.

112. Carl Reinhold Bråkenhielm, "Theology and the Origins of Customized Science" in *The Customization of Science: The Impact of Religious and Political Worldviews on Contemporary Science*, eds. Steve Fuller, Mikael Stenmark and Ulf Zackariasson (London: Palgrave Macmillan, 2014), 121.

113. Alister McGrath, *A Scientific Theology, Volume 1, Nature* (Edinburgh: T & T Clark, 2003), 140.

114. Hooykaas, *Fact, Faith, and Fiction*, 12.

115. Peter Harrison, *The Territories of Science and Religion* (Chicago: University of Chicago Press, 2014), 23-24.

practical and empirical level.[116] Hooykaas explains that "although the Greek atomists made Chance into Necessity *(ananke),* it was a blind necessity, not representing a rational plan. They were not looking for a fixed order (though they did have to admit some fixed principles in nature such as the indivisibility of atoms and the intrinsic heaviness of matter). Their system did not purport to further scientific creativity."[117] Thus, says Ratzsch, the "general Greek view was in various ways philosophically fruitful, but it did not directly result in any enduring tradition that was identifiably scientific, in the sense of the later Scientific Revolution. In fact, several of the aspects of Greek thought . . . may have hindered development of anything like modern science."[118] In contrast to the Greek philosophical mindset, Jews and Christians believed that the ways of nature, as the product of the Divine Mind, were reflections of reason and that "even those aspects of nature that threatened human safety were not lawless in themselves. They served God's purposes and had laws of their own, even if unknown to humans (Job 28:25-27)."[119]

3. That God Created the Human Mind to Comprehend God's Cosmos

Since God's creative activity in the cosmos reflects the rationality of the Divine Mind, Christians believe that the inner workings of the cosmos "are open to human comprehension, at least in principle."[120] As historian of science Christopher Kaiser explains, "The creation of all things by God, the consequent order and rationality of the cosmos, and the ability of human reason to comprehend this order all stem from the Judeo-Christian belief in creation, dating back at least to the second century BCE."[121] In this way, says theologian Alister McGrath, "human rationality thus bears a created, contingent relationship to—but is not identical with—divine rationality."[122] Affirming that the natural world could be comprehended, "early Christian scientists sought intelligible order in nature, regarding it as an indication of God's rational plan for the universe."[123]

116. Hannam points out that one of the reasons for thi, is that Greek philosophers generally saw trades as beneath them. "Greek philosophers, like Plato and Aristotle…thought that any kind of trade was beneath the dignity of intellectuals," *The Genesis of Science,* 141.

117. Hooykas, *Fact, Faith and Fiction*, 18

118. Ratzsch, "The Nature of Science," 57.

119. Christopher B. Kaiser, "Early Christian Belief in Creation and the Beliefs Sustaining the Modern Scientific Endeavor," in *The Blackwell Companion to Science and Christianity*, ed. J. B. Stump and Alan G. Padgett (Malden, MA: Blackwell, 2012), 6.

120. Ibid.

121. Ibid., 10.

122. Alister E. McGrath, *The Open Secret: A New Vision for Natural Theology* (Maiden, MA and Oxford: Blackwell-Wiley, 2008), 192.

123. Paul Davies, "The intelligibility of nature," in *Scientific Perspectives on Divine Action: Quantum Cosmology and the Laws of Nature*, eds. Robert J. Russell, Nancey Murphy, and C.J. Isham (Berkeley, CA: CTNS and Vatican Observatory Publications, 1999), 149-64.

4. The Created Contingency of the Cosmic Order

According to the Christian theological context within which the natural sciences developed, "God is the creative ground and reason for the contingent but rational unitary order of the universe."[124] The "Christian doctrine of creation" affirms that "the universe is both inherently intelligible and inherently contingent, its intelligibility reflecting its contingent origins in the rationality of God."[125] The belief that the order of the world is contingent rather than necessary is ultimately grounded in the Christian conception of the freedom of God.[126] Inherent in the Christian doctrine of *creatio ex nihilo*, which provided the conceptual matrix for early modern science, is the belief that God was free to choose how to create the universe. "Biblical thought held that the world's order is contingent rather than necessary. If God created both form and matter, the world did not have to be as it is, and one has to observe it to discover the details of its order."[127] God "was not in any way constrained either to create or not to create it in the way that He did. It is therefore not a necessary universe in the sense that it had to be created or could not have been created otherwise."[128] Given this understanding of nature, one can never say *a priori* (independently of observation) how God *must have* acted, and thus one can never say *a priori* how God's creation must behave. To obtain true knowledge about God's creation one must proceed in an *a posteriori* manner—by studying the material creation and by conducting experiments.[129] Thus early scientists such as "Gassendi described a world utterly contingent on divine will. This contingency expressed itself in his conviction that empirical methods are the only way to acquire knowledge about the natural world and that the matter of which all physical things are composed possesses some properties that can be known only empirically."[130] More recently, the essential affirmation of the contingency of the cosmic order "can be seen as lying behind both James Clerk Maxwell's insistence that there exists an inner relation between the laws of the mind and the laws of nature, and Albert Einstein's belief in a 'pre-established harmony' between the intelligibility of the independent world and the perceiving subject."[131]

5. The Independent Reality of the Created Cosmos

124. Artigas, *Mind of the Universe*, 15.

125. McGrath, *Open Secret*, 237.

126. Kaiser, "Early Christian Belief in Creation," 5. McGrath writes, "The creator is to be regarded as free of limitations imposed by the 'inertia of a prior reality'" (McGrath, *A Scientific Theology,* 1.195).

127. Barbour, *When Science Meets Religion,* 48.

128. Hodgson, *Theology and Modern Physics*, 26. See also Osler, *Divine Will and the Mechanical Philosophy*.

129. Michael Foster, "Greek and Christian Ideas of Nature," *The Free University Quarterly* 6 (1959): 125; McGrath, *Scientific Theology,* 2.139.

130. Osler, *Divine Will and the Mechanical Philosophy,* 1.

131. McGrath, *The Open Secret*, 237.

Related to the contingency of the order in the physical world is the notion of metaphysical realism. Metaphysical realism is grounded in the Jewish affirmation that God created the natural world to possess a significant degree of relative autonomy or independence.[132] Inheriting the metaphysical framework of its Jewish forbearers, the Christian theological tradition clearly presupposed and applied a philosophical faith in the existence of the external world, which has a structure that is independent from the human mind.[133] In the Jewish and Christian understandings, the material creation exists independently of the observer because God the creator exists and bestowed existence on both the human observer and the created objects being observed. The reality of both the external world and the human observer are affirmed because they are the creation of the same God.[134] The material world is understood as having its own reality owing to the fact that creation is independent or distinct from the Creator.[135]

"On the Christian conception . . . nature is made by God, but *is not God.* There is an abrupt break between nature and God. Divine worship is to be paid to God alone, who is *wholly other than nature.* Nature is not divine."[136] Barbour refers to this presupposition about the independent reality of the cosmos as a belief in the dedivinization or desacralization of nature.[137] As the independent creation of God, "the Christian cosmos is not inhabited by deities. Yet, as a divine creation it does bear deep theological significance."[138] Within the religions of the ancient word, Christians and Jews were unique in their denial of the divinity of the celestial bodies and "this skepticism was motivated by a theological worldview."[139] Because of this disbelief in the divinity of the sun, moon, earth, planets, and stars, Christians were often labeled as atheists and they were lumped together with the Epicureans who did not believe in any gods at all. The Neoplatonist philosopher Celsus and other educated pagans ridiculed Jews and Christians for their impiety in this matter. The atheist reputation of Christians continued into late antiquity with the Aristotelian philosopher Simplicius, "being horrified at the blasphemy" of the Christian philosopher John Philoponus (490-570), "who denied divinity to heavenly bodies."[140] Following the thought of Basil of Caesarea, Philoponus' theology led him to believe "that the motion of the heavens was to be explained by a 'motive force' imparted by God at the moment of creation."[141]

132. Christopher Kaiser, "Early Christian Belief in Creation," 7.

133. McGrath, *Scientific Theology*, 2.199.

134. Ibid., *2*.172, 228.

135. "The reality of God and the derived and contingent reality of the creation can thus be seen as distinct" (Ibid., 2.228).

136. Foster, "Greek and Christian Ideas of Nature," 123-24; See also Artigas, *The Mind of the Universe*, 22.

137. Barbour, *When Science Meets Religion,* 48.

138. Harrison, *Territories*, 53.

139. Ibid.

140. Ibid.

141. Ibid.

Philoponus's view of the independence and reality of the creation "supposed a unified theory of dynamics" where all natural motion was imparted upon creation by God. Philoponus's conception of impetus subsequently influenced Galileo and all those early scientists who would follow in his footsteps.

6. The Unity of Creation as Grounded in the Unity of God

The affirmation of the unity and uniformity of the physical universe was likewise a core belief emerging from a Judeo-Christian understanding of the unity of creation as the product of a single Creator. While many ancient schools of thought "drew a sharp line between the starry heavens and the terrestrial realm," the Christian tradition insisted on "a single physics for both heaven and earth."[142] This conception of the cosmos had become well established in the early church and was passed down to later Islamic and medieval Christian thinkers. It was then handed on from the leading natural philosophers of the Middle Ages to the practitioners of early modern science. When early modern scientists, such as Isaac Newton, argued for the universality of the laws of nature they justified this principle in theistic terms. Newton says, "If there be an universal life and all space be the sensorium of a thinking being [(God)] who by immediate presence perceives all things in it, [then] the laws of motion arising from life or will may be of universal extent."[143] In the nineteenth century, the "quest for a unification of electricity, magnetism, and optics, culminating in the work of James Clerk Maxwell, was still inspired by this theological ideal."[144] Theological presuppositions about the unity of creation also clearly motivated Michael Faraday in his scientific quest to discover the fundamental principles underlying electromagnetism and electrochemistry. As historian of science Colin Russell says, "No doubt Faraday's belief in the unity of the forces of matter was reinforced by his faith in a Creator who made the whole universe work together in harmony."[145] The influence of this theological affirmation also played a vital role in the development of cosmological theory in the 20th century. According to Brooke, "the inculcation of a Jewish monotheism early in life had a lasting effect in the way Einstein was driven, as

142. Christopher Kaiser, "The Creationist Tradition in the History of Science," *Perspectives on Science and Christian Faith* 45 (June 1993): 80-89.

143. Ratzsch, "The Nature of Science," 65. A *sensorium* is the sum of an organism's perception, the "seat of sensation" where it experiences and interprets the environment it lives within.

144. Kaiser, "The Creationist Tradition in the History of Science," 80. McGrath observes, "Since the uniformity of nature is an unjustified (indeed, circular) assumption within any non-theistic world-view, it could be argued that there is no firm basis upon which to engage in scientific activities, other than the belief that the regularities observed locally prove universal" (McGrath, *Scientific Theology*, 2.153).

145. Colin Russell, *Michael Faraday: Physics and Faith* (New York: Oxford University Press, 2000), 105.

many physicists still are, to seek a theory that would unify the fundamental physical forces."[146]

Particular and Contextual Metaphysical Presuppositions of Science

In addition to the *general* philosophical presuppositions that are provided—both historically and presently—there are also *particular presuppositions* or metaphysical assumptions that correspond to particular *metaphysical frameworks* and *research paradigms* within which scientific theorizing may take place.[147] These particular metaphysical assumptions and paradigms play a more circumscribed role within scientific theorizing than the general presuppositions and are often related to certain stages in the historical development of a given scientific theory.

For example, the commandment to humans in Genesis to exercise dominion over nature played an important role in the rise of early modern science that it no longer plays today. In the Middle Ages many believed "that Adam's original dominion over the creatures in the Garden of Eden consisted in a mental mastery of what it was that they represented."[148] One consequence of the Fall was that this original knowledge (or *science*) was lost, and the powers of the mind—"sense, imagination, reason, understanding, intelligence, and moral discernment—were distorted by sin." The recapturing of this lost mastery and knowledge of nature "could be achieved only if the powers that had originally made it possible were 'cleansed by righteousness, trained by learning, and perfected by wisdom.'"[149] The scientific enterprise that began in the late medieval period was aimed at gaining knowledge of the natural world in order to restore to the human mind some of its original powers and perfections. In this way, says Harrison, the biblical injunction to exercise dominion, "underpinned the modern scientific project, providing an important source of motivation for the investigation of nature and giving religious legitimacy to a project that . . . was more vulnerable in its early stages than we have sometimes assumed."[150]

As another example, consider the period when the geological sciences were first developing in seventeenth and eighteenth century Europe.[151] At this time one important particular presupposition that was a matter of significant debate between geologists was related to the question of whether the planet Earth had a beginning and changed progressively through time, or alternatively, whether Earth

146. John H. Brooke, "Preface," in *Science in Theistic Contexts: Cognitive Dimensions, Osiris 16*, eds. John H. Brooke, M.J. Osler, J.M. Van der Meer (Chicago: University of Chicago Press, 2001), viii.

147. Scientific research paradigms are "standard examples of scientific work that embody a set of conceptual and methodological assumptions." See Barbour, *Religion in an Age of Science,* 51.

148. Peter Harrison, *Territories*, 65.

149. Ibid., 66.

150. Ibid., 137

151. For a detailed discussion see Joshua Moritz, *Science and Religion*, 44-48.

was *infinitely old (*without beginning or end) and characterized by non-progressive cyclical geological processes.[152] The first view is known as Historical Geology and the second view—an idea that had been promoted by Aristotle and other ancient thinkers—is Aristotelian Eternalism (or Geologic Eternalism). Before the relevant empirical evidence was available to decide between the two alternative theories of time, history, and progressive change as it related to Earth's processes, discussions among early geologists about the timescale of the world was deeply colored by a "clash of theologies." As historian of geology Martin Rudwick explains, this "was not a case of 'Religion versus Science,' but of one religious view of the world against another."[153] At that point in time, there was not conclusive empirical evidence to demonstrate whether the planet Earth had a physical beginning or whether it was, in fact, eternal. The working assumption that Earth was a historical entity thus served as a particular presupposition that, as evidence was accumulated in its favor, would—in time—no longer be a matter of philosophical or theological faith.

A third example of a particular presupposition is found in Charles Darwin's context of discovery. At the core of Darwin's scientific quest to establish the common ancestry of all life was a *theologically* and *morally* inspired conviction in the ancestral unity of humanity.[154] This conviction motivated and drove Darwin's research agenda. According to Darwin's biographers, Adrian Desmond and James Moore, "Rather than seeing 'the facts' force evolution on Darwin, "we find a *moral* passion firing his evolutionary work. He was quite unlike the modern 'disinterested' scientist who is supposed (supposed, mark you) to derive theories from 'the facts' and only then allow the moral consequences to be drawn."[155] The notion of human unity—along with the corresponding rejection of slavery—was a key element of Darwin's family heritage. "Adamic unity and the brotherhood of man were axiomatic in the anti-slavery tracts that he and his family devoured and distributed. It implied a single origin for black and white, a shared ancestry."[156] When Darwin began his evolutionary quest in search of human origins, his "starting point was the abolitionist belief in blood kinship, a 'common descent'" for all human beings. And this deep conviction and faith in the unity of the human race "was the *unique* feature of Darwin's peculiar brand of evolution."[157] As evidence for the common ancestry of humanity and all of life

152. Alan H. Cutler, "Nicolaus Steno and the Problem of Deep Time," in *The Revolution in Geology from the Renaissance to the Enlightenment,* ed. Gary D. Rosenberg (Boulder, CO: Geological Society of America, 2009), 143-48, 143.

153. Martin Rudwick, *Bursting the Limits of Time: The Reconstruction of Geohistory in the Age of Revolution* (Chicago: University of Chicago Press, 2005), 118

154. For a detailed discussion see Joshua M. Moritz, *Science and Religion: Beyond Warfare and Toward Understanding* (Winona, MN: Anselm Academic, 2016), 48-51.

155. Adrian Desmond and James Moore, *Darwin's Sacred Cause: How a Hatred of Slavery Shaped Darwin's Views on Human Evolution* (Boston: Houghton Mifflin Harcourt, 2009)*,* xviii.

156. Desmond and Moore, *Darwin's Sacred Cause,* 54, xvii.

157. Desmond and Moore, *Darwin's Sacred Cause,* xvii.

was increasingly found, the particular presupposition of Adamic Unity became less important as a guiding principle.

Whether scientists are aware of them or not, particular presuppositions never disappear from science. All data collected via the scientific method and the interpretation of this data is dependent upon the particular research paradigm within which that data is considered. Such data is never free of the theoretical assumptions related to a given paradigm and the choice of one research paradigm over another is not dictated by scientific research in itself.[158] Unless a scientist is so radically aware of his or her own metaphysical presuppositions that he or she can systematically strive to replace them with other presuppositions, scientific theories will inevitably be formulated and interpreted in such a way as to achieve consistency with dominant metaphysical presuppositions.

Conclusion

Because non-empirical shaping principles are a key part of what science *is*—as Thomas Kuhn and many other historians and philosophers of science have shown—science really does need faith. Such faith *within* science takes a number of different forms, including ethical values, aesthetic principles, philosophical commitments, metaphysical presuppositions, and theological motivations. Philosopher of science Delvin Ratzsch explains, "Doing science requires use of presuppositions involving criteria for theory construction, theory evaluation, and boundaries of concept legitimacy, plausibility structures, and a host of other matters."[159] Since such factors both precede and inform the practice of science, "science itself cannot provide the rational justification for them."[160] Science, then, appears to critically depend upon values and presuppositions that are not the result of scientific discovery or testing. Since they "lie somewhere beyond the borders of science," they cannot be directly evaluated through empirical investigation.[161] Many of the values and presuppositions that the practice science is founded upon come either directly or indirectly from the specific theological context of the Judeo-Christian tradition. In fact, it would seem that the Judeo-Christian understanding of a real and unified cosmic physics with an intelligible, orderly, and rational structure that could and should be discovered

158. See Barbour, *Religion in an Age of Science,* 52.

159. Delvin Ratzsch, "The Nature of Science," in *Science and Religion in Dialogue*, ed. M. Y. Stewart (Oxford: Wiley-Blackwell, 2010), 47.

160. Ibid.

161. Ibid.

was a necessary (though not sufficient) condition for the rise of science.[162] Today, scientists can either take these presuppositions for granted as givens (albeit in a rather philosophically arbitrary manner), or seek to provide a deeper philosophical justification for them by appealing to the theological worldview that they emerge from. Alternatively, scientists motivated by non-Judeo-Christian or atheistic social contexts may decide to reject specific presuppositions (such as Ockham's Razor, the rationality of nature, the intelligibility of nature, ontological realism, or the unity of the laws of nature) and seek to find other guiding presuppositions from non-religious or non-Judeo-Christian contexts. For the present, the vast majority of science is produced under the guiding light of theistically derived philosophical presuppositions. As Davies says, "Science began as an outgrowth of theology, and all scientists, whether atheists or theists accept an essentially theological worldview."[163] Whether or not there can be a different science, however, a science with alternative—non-Judeo-Christian or atheistic—guiding assumptions, and whether or not such a science can thrive as a knowledge producing enterprise, will remain to be seen if and when individual scientists decide to give up the classical philosophical assumptions of science in exchange for a novel set of assumptions.

162. This point is extensively developed by Cambridge historian of science Joseph Needham, the greatest Western interpreter of the history of science in China. Needham has argued that this Judeo-Christian metaphysical faith in the rationality of the Creator was one of the key reasons that theoretical science developed and flourished in a European context in a way that it never did in a Chinese context—even though technology in China was well-developed. Needham explains that in China, "the highest spiritual being known and worshipped was not a Creator in the sense of the Hebrews and the Greeks. It was not that there was no order in Nature for the Chinese, but rather that it was not an order ordained by a rational personal being, and hence there was no guarantee that other rational personal beings would be able to spell out in their own earthly languages the pre-existing divine code of laws which he had previously formulated. There was no confidence that the code of Nature's laws could be unveiled and read, because there was no assurance that a divine being, even more rational than ourselves, had ever formulated such a code capable of being read." Joseph Needham, *Human Law and the Laws of Nature in China and the West* (L.T. Hobhouse Memorial Trust Lecture, Cambridge University Press, 1951), 41-42.

163. Paul Davies, *Are We Alone?* (New York: Basic Books, 1995), 138.