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By design: James Clerk Maxwell and the evangelical unification of science

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Abstract. James Clerk Maxwell's electromagnetic theory famously unified many of the Victorian laws of physics. This essay argues that Maxwell saw a deep theological significance in the unification of physical laws. He postulated a variation on the design argument that focused on the unity of phenomena rather than Paley's emphasis on complexity. This argument of Maxwell's is shown to be connected to his particular evangelical religious views. His evangelical perspective provided encouragement for him to pursue a unified physics that supplemented his other philosophical, technical and social influences. Maxwell's version of the argument from design is also contrasted with modern 'intelligent-design' theory.

The most important machine in the history of science and religion is a watch. Specifically, a watch that William Paley imagined finding while crossing a heath. Paley said anyone, even someone who had never seen a watch before, would recognize the contrivance and complexity of its many moving parts. Contrivance could only result from intentional design, so 'the inference, we think, is inevitable; that the watch must have had a maker'.[1] Paley argued that just as the complexity of the watch inevitably drove one to acknowledge a watchmaker, so too the complexities of the natural world demanded a creative, kind God. Paley called this conclusion 'invincible'.[2] Many people agreed, particularly in Britain, and his book was read widely.[3] The complexity of living things seemed to have no explanation other than God, an argument that was resurrected at the end of the twentieth century in the form of 'intelligent design' or ID.

Intelligent design has relied on different machines – molecular ones. Michael Behe claimed that the complexity of biochemistry, like the watch on the heath, demanded a designer.[4] Biochemical functions, he said, were like a mousetrap: if any part were removed, it could not function. They were therefore 'irreducibly complex' and could not

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1 William Paley, *Natural Theology*, Boston: Gould and Lincoln, 1872 (1802), p. 6.

2 Paley, op. cit. (1), p. 12. Paley did not think Christianity could be proven by natural theology, and thus recommended also reading his *Evidences*.

3 John Hedley Brooke, *Science and Religion: Some Historical Perspectives*, Cambridge: Cambridge University Press, 1991, pp. 198–203.

4 Michael Behe, *Darwin's Black Box*, New York: Free Press, 1996; and *idem*, 'Molecular machines: experimental support for the design inference', in Robert Pennock (ed.), *Intelligent Design Creationism and Its Critics*, Cambridge, MA: MIT Press, 2001, pp. 241–256.

have developed from gradual natural processes.[5] Both Paley and Behe argued that a certain level of complexity could never be explained by naturalistic science, and thus the search for such explanations must stop. Modern scientists and philosophers sometimes call this the 'science-stopper' problem: certain kinds of explanation require that scientists simply accept that a phenomenon is not understandable in terms of natural laws or processes. Science as an enterprise, then, must stop. As an argument from ignorance, intelligent design shuts the door on possible future progress. Many scientists and philosophers point to this problem as showing why design arguments do not belong in science.[6]

But not all machines are valued for their complexity, and not all design arguments make science stop. Some design arguments, rather than demanding that science halt, demand that science continually progress. This paper examines such arguments as they were deployed by the evangelical Christian and noted physicist James Clerk Maxwell.[7] Maxwell embraced vigorously the claims of natural theology (the existence, goodness and so on of God), but his evangelical religiosity gave him a rather different perspective from Paley's, with consequent divergences in how to value science. Machines were important in Maxwell's vision of a divinely designed universe, too, but he would disagree with Paley and Behe about exactly what aspect of the machine showed God's blueprints.

Maxwell's machine was a peculiar one: tiny elastic spheres and idle wheels filling space. These spinning wheels were an early hypothesis proposed by Maxwell to show how a universal ether could support and explain the various forces of electricity and magnetism. This intricate mechanical hypothesis eventually led to a highly mathematical theory that showed deep connections among electrical, magnetic and optical phenomena.[8] This unification of forces, which survives today as his eponymous equations, helped set one of the major agendas of modern physics. But to Maxwell it had

5 Behe, *Darwin's Black Box*, op. cit. (4), pp. 39–45.

6 For example, see the decision *Tammy Kitzmiller et al.* v. *Dover Area School District*, 66 (2005).

7 Maxwell's theological views are discussed in Paul Theerman, 'James Clerk Maxwell and religion', *American Journal of Physics* (April 1986) 54, pp. 312–317; Jordi Cat, *Land, Lines, and Toys: Becoming James Clerk Maxwell* (forthcoming); Thomas Torrance, 'Christian faith and physical science in the thought of James Clerk Maxwell', in *idem*, *Transformation and Convergence in the Frame of Knowledge*, Belfast, 1998, pp. 214–242; and Crosbie Smith, *The Science of Energy*, Chicago: University of Chicago Press, 1998, Chapter 11.

8 On the development of Maxwell's theory overall see P.M. Harman, *The Natural Philosophy of James Clerk Maxwell*, Cambridge: Cambridge University Press, 1998, pp. 98–124; Daniel Siegel, *Innovation on Maxwell's Electromagnetic Theory*, Cambridge: Cambridge University Press, 1991; *idem*, 'Thomson, Maxwell, and the universal ether in Victorian physics', in G.N. Cantor and M.J.S. Hodge (eds.), *Conceptions of Ether: Studies in the History of Ether Theories 1740–1900*, Cambridge: Cambridge University Press, 1981, pp. 239–268; Crosbie Smith, op. cit. (7), pp. 218–238; M. Norton Wise, 'The mutual embrace of electricity and magnetism', *Science* (1979) 4387, pp. 1310–1318; *idem*, 'The Maxwell literature and British dynamical theory', *Historical Studies in the Physical Sciences* (1982) 13, pp. 175–205; Olivier Darrigol, *Electrodynamics from Ampère to Einstein*, Oxford: Oxford University Press, 2000, pp. 149–155; Jed Z. Buchwald, 'Modifying the continuum: methods of Maxwellian electrodynamics', in P.M. Harman (ed.), *Wranglers and Physicists: Studies on Cambridge Physics in the Nineteenth Century*, Manchester: University of Manchester Press, 1985, pp. 225–241; and Simon Schaffer, 'Accurate measurement is an English science', in M. Norton Wise (ed.), *The Values of Precision*, Princeton: Princeton University Press, 1995, pp. 135–172.

an even greater significance: the unity of nature suggested by the mechanical ether was a key signpost leading one to the handiwork of God.

Maxwell on unification

Maxwell embraced the unification of natural laws suggested by his mechanical model, 'that the luminiferous and the electromagnetic medium are one'.[9] He was convinced that there was a true connection between optics and electromagnetism – that there was a fundamental principle hidden in the chaos of observable phenomena. For him, such unification was essential to the very notion of physical explanation: 'When any physical phenomenon can be described as an example of a general principle which is applicable to other phenomena the phenomenon is said to be explained.'[10] The primary conceptual tool Maxwell used for searching for such underlying principles was that of the 'analogy'.

By 'analogy' he meant 'that partial similarity between the laws of one science and those of another which makes each of them illustrate the other'.[11] More informally, and reflecting Maxwell's lifelong interest in comic poetry: 'Now, as in a pun two truths lie hid under one expression, so in an analogy one truth is discovered under two expressions.'[12] In simplest terms, a physical analogy was a claim of an underlying similarity of relations between two apparently different phenomena or sets of laws. For Maxwell, analogies were a powerful way to approach scientific problems. They functioned as a happy medium between unwarranted hypotheses and highly abstract mathematical theories.[13] They allowed one to describe something unfamiliar or complex (such as electromagnetism) in terms of something familiar or simple (such as idle wheels) without postulating completely speculative entities or discarding physical reasoning. His reliance on and confidence in analogies was certainly encouraged by his training in the Common Sense school of philosophy, which also emphasized the need for constant testing of analogies.[14]

Maxwell discussed several different kinds of analogy, but for the purposes of this essay I will concentrate on Maxwell's approach to analogous laws; that is, his interest in how different laws of nature appear to be analogous to one another, and might therefore be linked. A real analogy between disparate laws, such as

9 Maxwell to Michael Faraday, 19 October 1861, in P.M. Harman (ed.), *Scientific Letters and Papers of James Clerk Maxwell* (hereafter *SLP*), 3 vols., Cambridge: Cambridge University Press, 1990, vol. 1, pp. 685–86.

10 Maxwell, MS of 'On the ~~physical~~ dynamical explanations of electric phenomena', University Library, Cambridge, Add. MS 7655/Vc/10i.

11 Maxwell, 'On Faraday's lines of force', in *Scientific Papers of James Clerk Maxwell* (ed. W.D. Niven), 2 vols., Cambridge: Cambridge University Press, 1890, vol. 1, pp. 156.

12 Maxwell, 'Are there real analogies in nature?', *SLP*, vol. 1, p. 376.

13 Robert Kargon, 'Model and analogy in Victorian science: Maxwell's critique of the French physicists', *Journal of the History of Ideas* (1969) 30, pp. 423–436; and Siegel, 'Thomson, Maxwell, and the universal ether', op. cit. (8), p. 243.

14 Richard Olson, *Scottish Philosophy and British Physics 1750–1880*, Princeton: Princeton University Press, 1975, pp. 290–292. Jordi Cat argues for a variety of sources for Maxwell's reliance on analogies. See Cat, op. cit. (7), Chapter 7.

electromagnetism and optics, would suggest a real unification. The scientific role of analogies was in

> its application to the opinion, that all the phenomena of nature, being varieties of motion, can only differ in complexity, and therefore the only way of studying nature, is to master the fundamental laws of motion first, and then examine what kinds of complication of these laws must be studied in order to obtain true views of the universe. If this theory be true, we must look for indications of these fundamental laws throughout the whole range of science, and not least among those remarkable products of organic life, the results of cerebration (commonly called 'thinking'). In this case, of course, the resemblances between the laws of different classes of phenomena should hardly be called analogies, as they are only transformed identities.[15]

Analogy was a route to uncovering the 'fundamental laws' that underpinned all the varied phenomena of the universe, in this case suggested to be the laws of motion. Maxwell was here stating a methodological possibility, not necessarily a claim about nature. He was arguing that if there were true connections between the various laws of nature, then analogy could be a useful tool. But were there such true connections? He acknowledged that humans seemed to feel a compulsive need to search out such fundamental laws, regardless of whether they existed: 'the human mind cannot rest satisfied with the mere *phenomena* which it contemplates, but is constrained to seek for the principles embodied in the phenomena'.[16]

Maxwell was well aware of the psychological quirks of the human mind, however, and seriously considered the possibility that the unification of laws was only a feature of the mind and not of the physical world: 'are we to conclude that these various departments of nature in which analogous laws exist, have a real interdependence; or that their relation is only apparent and owing to the necessary conditions of human thought?'[17] It was entirely possible that the concept of an orderly, unified, well-organized universe was simply a human construction that we projected onto the world. To illustrate this, Maxwell presented two possible metaphors for the laws of nature:

> Perhaps the 'book,' as it has been called, of nature is regularly paged; if so, no doubt the introductory parts will explain those that follow, and the methods taught in the first chapters will be taken for granted and used as illustrations in the more advanced parts of the course; but if it is not a 'book' at all, but a *magazine*, nothing is more foolish to suppose than that one part can throw light on another.[18]

If nature were like a book, then there was a single argument – a common thread holding together the text that could be used to interpret and understand the whole. If so, then in physics, electricity could help you understand magnetism because they were both part of a single 'document'. But if nature were like a magazine, where the separate articles had nothing to do with one another and could even be written by different authors, there was no such assurance. A magazine has no single argument. Rather, it is a collection whose

15 Maxwell, 'Analogies', *SLP*, vol. 1, p. 380.

16 James Clerk Maxwell, 'Inaugural lecture at Aberdeen', in R.V. Jones, 'James Clerk Maxwell at Aberdeen, 1856–1860', *Notes and Records of the Royal Society of London* (June 1973) 28, pp. 57–81, 80–81, original emphasis.

17 Maxwell, 'Analogies', *SLP*, vol. 1, pp. 376–377.

18 Maxwell, 'Analogies', *SLP*, vol. 1, pp. 381–382, original emphasis.

elements may or may not have a connection to each other. There was no guarantee that any one article could help the reader understand any other. If this were the case, there would be no reason to think that electricity could help us understand magnetism. It was not immediately clear why scientists should choose one metaphor over the other. Whether nature was like a book or a magazine was of the highest importance for understanding it. But how was one to decide?

The design of nature

Maxwell was convinced that nature was like a book, and that its individual elements should be seen as manifestations of deeper unified principles. He thought that the connections between the laws of nature were, literally, a sign from above. Someone investigating physical laws 'will see as he advances that the laws of nature are not mere arbitrary and unconnected decisions of Supreme Power, but that they form essential parts of one universal system, in which infinite Power serves only to reveal unsearchable Wisdom and eternal Truth'.[19] An earlier draft of this passage (which also appears in Maxwell's Aberdeen inaugural lecture) made the role of laws as divine messenger even clearer, saying that physics revealed a world 'in which Wisdom and Truth are supreme, and Power is their minister'.[20]

Maxwell's claim that laws were 'parts of one universal system' was arguing that there was a plan to the interrelationship of natural laws. This interrelationship was a way that God communicated His existence, and it was the unity of laws that revealed this communication. An 'arbitrary' distribution of individual laws (like the articles of a magazine) would not suggest anything about a divine plan, but unification (like the chapters of a book) would be highly improbable and therefore was a kind of divine communication. God had a plan for the world, and part of that plan was designing natural laws to fit together like the pieces of a puzzle.

The unity of nature was a critical part of Maxwell's understanding of God. This unity was, he thought, one of the most powerful tools for seeing the deity at work. In a letter discussing whether scientists should try to relate specific parts of physics to scripture, Maxwell warned against such a task, but also asserted,

> At the same time I think that each individual man should do all he can to impress his own mind with the extent, the order, and the unity of the universe, and should carry these ideas with him as he reads such passages as the 1st Chap. of the Ep. to Colossians (see Lightfoot on Colossians, p. 182), just as enlarged conceptions of the extent and unity of the world of life may be of service to us in reading Psalm viii.; Heb. ii. 6, etc.[21]

The unity of nature was therefore guaranteed by theology. The scriptural passages Maxwell referred to here emphasized God's role as creator of the natural world ('For by him were all things created, that are in heaven, and that are in earth, visible and

19 Maxwell, 'Inaugural lecture at King's College, London', October 1860, *SLP*, vol. 1, p. 670. 'Unsearchable wisdom' is probably a reference to the Westminster Confession of Faith 5.4.

20 Maxwell Papers, Cambridge University Library, Add. MS 7655/Vh/1.

21 Maxwell to Charles John Ellicott, Bishop of Gloucester and Bristol, 22 November 1876, *SLP*, vol. 3, p. 418.

invisible') and the awe that God designed his creation for man ('What is man, that thou art mindful of him?').[22] Thus Maxwell was powerfully linking the unity and order of nature not just with divine creation itself, but also with the role of man in that creation. In the same letter he argued that we can see 'wisdom and power' in the uniformity of natural laws just as effectively as in the beneficial adaptations of living creatures: 'uniformity, accuracy, symmetry, consistency, and continuity of plan are as important attributes as the contrivance of the special utility of each individual thing'.[23] Maxwell could be sure that nature was like a book because he was familiar with its author, and he knew how that author wrote.

Maxwell's best-known statements on the uniformity of nature appeared in his famous 1873 lecture on molecules at the British Association for the Advancement of Science. He argued that new techniques of spectroscopy showed that in the Sun

> there are molecules vibrating in as exact unison with the molecules of terrestrial hydrogen as two tuning-forks tuned to concert pitch, or two watches regulated to solar time . . . Now this absolute equality in the magnitude of quantities, occurring in all parts of the universe, is worth our consideration.[24]

In addition to the spectroscopic evidence that molecules everywhere in space were identical, he pointed to simple chemical evidence of uniformity through time. Hydrogen liberated from rocks buried since time immemorial was identical to that manipulated in the Cavendish Laboratory. Borrowing John Herschel's metaphor of molecules as manufactured articles, he said this incredible uniformity among matter scattered through space and time indicated the hand of a divine manufacturer. Again, uniformity could only be explained through God.

At a glance, this argument might seem to be identical to Paley's. An object in nature appears to be the result of manufacture, therefore a manufacturer must exist. However, the core of Maxwell's argument was actually quite different. Paley emphasized *complexity* as the indicator of God's hand, Maxwell emphasized *unity*.[25] Whereas the Paley–Behe argument says that we can see design through our inability to understand complexity, Maxwell says that we see design through the unity revealed by our scientific efforts. More science revealed more design, not less. This is a strategy we will see Maxwell use again.

22 Colossians 1:16, Hebrews 2:6, and Psalm 8, New International Version.

23 Maxwell to Charles John Ellicott, Bishop of Gloucester and Bristol, 22 November 1876, *SLP*, vol. 3, p. 417.

24 James Clerk Maxwell, 'Address to the Mathematical and Physical Sections of the British Association', in *Scientific Letters and Papers of James Clerk Maxwell*, Cambridge: Cambridge University Press, 1870, p. 224.

25 Despite his prominence, Paley's version of the design argument was certainly not the only one used in the Victorian period. For examples, see D.W. Bebbington, 'Science and evangelical theology in Britain from Wesley to Orr', in David N. Livingstone, D.G. Hart and Mark A. Noll (eds.), *Evangelicals and Science in Historical Perspective*, New York: Oxford University Press, 1999, pp. 120–141, 133; Jonathan Topham, 'Science, natural theology, and evangelicalism in early nineteenth-century Scotland', in Livingstone, Hart and Noll, op. cit., pp. 142–174; Richard Yeo, 'The principle of plenitude and natural theology in nineteenth-century Britain', *BJHS* (1986) 19, pp. 263–82; as well as Topham's unpublished PhD dissertation, 'An infinite variety of arguments', Lancaster University, 1993.

It is important to note that Maxwell and Behe would agree on one point, that Darwinian evolution was not a reliable scientific theory. Maxwell's molecules lecture was intended to refute claims by John Tyndall that evolutionary hypotheses could explain virtually all natural phenomena. He argued that Darwinian evolution relied on pre-existing variation, and thus perfectly uniform molecules could never have evolved. His rejection of evolution was not the same as intelligent design, however. He pointed to the unity, not complexity, of nature, and did not make the case that scientific investigation must stop.[26]

Maxwell did not invoke the design argument naively. His approach was sophisticated, as he was well read in David Hume and other philosophers and was quite aware of the pitfalls of relying on divine action. An essay fragment of his on evidence for design had nearly half its length devoted to the dangers of such assertions. He listed three fallacies commonly associated with the design argument: putting a final cause where there should be a physical one, asserting incorrect physical connections, and reasoning from facts that are simply wrong.[27] He saw the first of those, invoking final causes, as the most dangerous. An overreliance on final causes could blind one to important facts and if used improperly could call a halt to natural investigations far too early. It was helpful as a guideline but required significant assistance:

> The doctrine of final causes, although productive of barrenness in its exclusive form, has certainly been a great help to enquirers into nature; and if we only maintain the existence of the analogy, and allow observation to determine its form, we cannot be led far from the truth.[28]

He did not want design to replace empiricism, observation or analysis. He wanted design to be something that would help science work better. His methodological prescript was that final causes were dangerous if used in isolation (one should not replace physical causes with divine ones); but if you are aware beforehand that there are final causes of some sort at work in nature, that can help guide you to observational truths about nature that you would have otherwise missed. Understanding the reality and character of God's actions could provide assurance that certain kinds of investigation would be fruitful, and keep one from going astray.

I am not arguing that Maxwell thought any hypothesis proved, or was proved by, any specific religious statements. He was willing to make broad, general claims about the theology of nature (such as in his molecules lecture), but was quite hesitant to directly link particular scientific ideas to any part of religious doctrine:

> But I should be very sorry if an interpretation founded on a most conjectural scientific hypothesis were to get fastened to the text in Genesis, even if by so doing it got rid of the old statement of the commentators which has long ceased to be intelligible. The rate of change of scientific hypothesis is naturally much more rapid than that of Biblical interpretations, so that if

26 Maxwell did make the case that science could not explain the beginning of the universe, but this was actually not distinctive of his design argument: this inability was agreed upon by agnostic and atheistic scientists such as T.H. Huxley and John Tyndall as well.

27 Maxwell, 'What is the nature of evidence of design?', *SLP*, vol. 1, p. 228.

28 Maxwell, 'Analogies', *SLP*, vol. 1, p. 382.

> an interpretation is founded on such an hypothesis, it may help to keep the hypothesis above ground long after it ought to be buried and forgotten.[29]

Further, he warned that any ties between religion and science should be sought by individual Christians, and could only reflect their own personal beliefs and experiences. Maxwell rejected an invitation to join the Victoria Institute, a group devoted to bringing together science and religion, by warning that such links should not be institutionalized:

> I think men of science as well as other men need to learn from Christ, and I think Christians whose minds are scientific are bound to study science that their view of the glory of God may be as extensive as their being is capable of. But I think that the results which each man arrives at in his attempts to harmonise his science with his Christianity ought not to be regarded as having any significance except to the man himself, and to him only for a time, and should not receive the stamp of a society. For it is of the nature of science, especially of those branches of science which are spreading into unknown regions to be continually——[here the MS ends].[30]

An important point in both these passages was that science was expected to advance and change rapidly in a way that religion (specifically Christianity) was not. Maxwell was concerned to protect both science and religion from this mismatch. He did not think religion could change rapidly because it was to be anchored to scripture, which was not subject to significant revision. Interpretations could change, but since the subject of interpretation was fixed, he did not expect such changes to be rapid or dramatic. Science, on the other hand, had no such firm anchor, and could change quickly with new discoveries or formulations. Neither of these rates of change were a problem unto themselves – difficulties only arose when one expected the rates of change to match. The danger was to tie a particular scientific hypothesis to a particular point of scriptural interpretation (for example, God's creation of light in Genesis was the formation of the idle-wheel ether) and thus either retard science to the speed of religious interpretation or dangerously accelerate the latter to a scientific pace. Harmonization of science and religion should instead rely on broad theological truths (for example, God as benevolent creator) and broad scientific guidelines (e.g. physical forces are fundamentally unified). At this high level, the rates of change of both science and religion could be expected to be glacial and therefore safe.[31] Note that he did expect even harmonizations of these sorts to change ('and to him only for a time'). The progress of science was axiomatic for Maxwell.

This continuous progress of scientific thought also played an important role in the way Maxwell thought God had designed the laws of nature. The divine uniformity of natural laws had implications even beyond the simple recognition of a creator. Natural laws

29 Maxwell to Charles John Ellicott, Bishop of Gloucester and Bristol, 22 November 1876, *SLP*, vol. 3, p. 418.

30 Maxwell, 'Draft letter to Francis W.H. Petrie', 15 March 1875, *SLP*, vol. 3, p. 194.

31 Different rates of change for particular elements of science are discussed in Peter Galison, *How Experiments End*, Chicago: University of Chicago Press, 1987, pp. 246–57. In Galison's terms, Maxwell would say that science and religion should harmonize their 'long-term constraints'.

were designed with the special feature that they are meant to be discovered – once we understand some science

> we are prepared to see in Nature not a mere assemblage of wonders to excite our curiosity but a systematic museum designed to introduce us step by step into the fundamental principles which are displayed in the works of Creation.[32]

In particular, the unification of laws was intended for discovery. The connections of natural laws were 'systematic' in that they were carefully designed to attract the attention of humans and lead them to deeper and deeper principles. Laws were laid out like a trail of breadcrumbs to guide the attentive from diverse phenomena to unification via strategic connections. Scientific investigation, then, and particularly the search for unified physical laws, was a task given divine assent and even encouragement. Maxwell's God wanted him to understand the world in deeper and deeper terms. His theology gave him a powerful set of tools for understanding the natural world, and for guiding his investigations in physics. He argued that God made the universe obey laws that were fundamentally unified and that He wanted humans to discover that unity.

Evangelical attitudes

In examining such issues it is important to be specific about what one means by 'religion' or even by 'Christianity'. Design arguments and natural theology varied in location, time and doctrinal context.[33] Maxwell was a conservative evangelical Christian who had a specific understanding of the nature of God. His thinking about the relationship between God and nature was shaped heavily by his evangelical outlook.

Evangelical Christianity was a major force in Victorian thought and society. It was not a separate sect, but rather a cross-denominational movement to reconceptualize the relationship of God and man through individual reflection and action.[34] This was a 'religion of the heart', with an emphasis on conversion, sin and grace, and moving away from the rationalism of the Enlightenment in an attempt to resurrect the lost, primitive Church uncontaminated by human failings.[35] In the evangelical framework man was naturally depraved via original sin and was wholly other from the divine. Life was the opportunity to prove one's morality through the exercise of free will to choose a godly life over a worldly one. A Christian could approach the divine only by embracing that which God offered. Religious truth was beyond human understanding, except insofar as

32 Maxwell, 'Aberdeen', op. cit. (16), p. 71.

33 John Brooke and Geoffrey Cantor, *Reconstructing Nature: The Engagement of Science and Religion*, Oxford: Oxford University Press, 1998, pp. 141–246. Brooke, op. cit. (3), pp. 192–225. Matthew Stanley, 'A modern natural theology?', *Journal of Faith and Science Exchange* (1999) 3, pp. 105–112.

34 A useful start for understanding evangelicalism is David W. Bebbington, Mark Noll and George A. Rawlyk (eds.), *Evangelicalism: Comparative Studies of Popular Protestantism in North America, the British Isles, and Beyond, 1700–1990*, Oxford: Oxford University Press, 1994; and David W. Bebbington, *Evangelicalism in Modern Britain: A History from the 1730s to the 1980s*, London: Unwin Hyman, 1989. On its relation to science see Livingstone, Hart and Noll, op. cit. (25).

35 Boyd Hilton, *The Age of Atonement: The Influence of Evangelicalism on Social and Economic Thought, 1785–1865*, Oxford: Oxford University Press, 1991, p. 8.

God chose to reveal portions of it through scripture and personal contact with the faithful. Evangelicalism focused strongly on the importance of scripture, particularly against those who asserted the sufficiency of human reason or church authority.[36]

Maxwell was raised in Scotland in both the Presbyterian and Episcopal traditions, but only became an evangelical after 1853. In that summer he was studying for the Tripos exam at Cambridge while staying with his friend George Wood Henry Tayler's uncle, the Reverend C.B. Tayler, who was an evangelical rector in Suffolk. While studying he collapsed with a dangerous fever which resulted in an intense conversion experience under the ministrations of his host. Describing his newfound evangelical outlook after returning to Cambridge, Maxwell wrote,

> I maintain that all the evil influences that I can trace have been internal and not external, you know what I mean – that I have the capacity of being more wicked than any example that man could set me, and that if I escape, it is only by God's grace helping me to get rid of myself, partially in science, more completely in society, – but not perfectly except by committing myself to God as the instrument of His will, not doubtfully, but in the certain hope that that Will will be plain enough at the proper time.[37]

The emphasis on sin, grace and leading a life governed by God's will was distinctive of Victorian evangelicals.[38] Shortly after his conversion experience, Maxwell fell under the spell of the controversial theologian F.D. Maurice. Maurice had a deep influence on Maxwell, but largely in the realm of social activism and education, not in the theology of nature discussed here.[39]

Maxwell's correspondence with his wife gives us a particularly valuable window into his evangelicalism. Here he describes a visit to see his friend and future biographer Lewis Campbell deliver a sermon:

> He showed up sin as the universal poison … Lewis preached on 'Ye must be born again,' … Then he described the changes on a man new-born, and his state and privileges. I think he has got a good hold of the people, and will do them good and great good.[40]

Divine grace, submission to God's will, and Christology were constant themes:

> Think what God has determined to do to all those who submit themselves to His righteousness and are willing to receive His gift. They are to be conformed to the image of His Son, and when that is fulfilled, and God sees that they are conformed to the image of Christ, there can be no more condemnation, for this is the praise which God Himself gives, whose judgment is just. So we ought always to hope in Christ, for as sure as we receive Him now, so sure will we be made conformable to His image.[41]

36 Bebbington, op. cit. (34), pp. 2–3.

37 Maxwell to Rev. C.B. Tayler, 8 July 1853, *SLP*, vol. 1, pp. 220–221.

38 The role of the will in Maxwell's science and religion is discussed in Matthew Stanley, 'The pointsman: Maxwell's demon, Victorian free will, and the boundaries of science', *Journal of the History of Ideas* (2008) 69, pp. 467–491.

39 Maxwell's relationship with Maurice is discussed further in Stanley, op. cit. (38); *idem*, 'The Working Men's College', forthcoming; and Cat, op. cit. (7).

40 Maxwell to K.M. Dewar, 9 May 1858, in Lewis Campbell and William Garnett, *The Life of James Clerk Maxwell*, London: Macmillan and Co., 1882, p. 311.

41 Maxwell to his wife, 23 June 1864, in Campbell and Garnett, op. cit. (40), pp. 338–339.

Almost every letter (though the record is far from complete) makes reference to scripture:

> I have been back at 1 Cor. xiii. I think the description of charity or divine love is another loadstone for our life – to show us that this is one thing which is not in parts, but perfect in its own nature, and so it shall never be done away. It is nothing negative, but a well-defined, living, almost acting picture of goodness; that kind of it which is human, but also divine. Read along with it 1 John iv., from verse 7 to end; or, if you like, the whole epistle of John and Mark xii.[42]

Maxwell was a serious biblical scholar, often inspecting passages in their original language. His frequent use of the metaphor of the book of nature is given deeper meaning by his placement among the evangelicals, who attributed tremendous power to the written word.[43] I have only been able to provide here a small taste of the evangelical religious outlook that heavily shaped Maxwell's adult life, but it is sufficient to provide a sense of the values and beliefs in play.

Victorian evangelicals had mixed feelings about science.[44] The standard story has been that evangelicals were suspicious of Enlightenment claims that natural theology and rational religion by themselves could suffice as the foundations of Christianity. They, in contrast, wanted to reserve that role for scripture. Further, humans, steeped in sin and error as they were, could not hope to penetrate the mysteries of the universe with their own abilities. These seemed to combine into a strong anti-science position. Recently historians have warned that this story, while containing elements of truth, should not be taken too far.[45] We now have several studies that show some of the fruitful interactions between science and Victorian evangelicalism.[46] A more complete picture might be this: evangelicals were often sceptical that the natural world could provide significant religious insight vis-à-vis scripture, but they were not on the whole hostile to science.

And those evangelicals that did embrace science had a distinctive approach to thinking about the natural world. John Brooke has argued that an 'archetypical evangelical scientist' would probably have a biblically informed philosophy of nature, be averse to speculative hypothesis due to humility before God, be sensitive to the uses and limitations of natural theology, and insist on harmony between true science and true religion.[47]

42 Maxwell to his wife, 22 June 1864, in Campbell and Garnett, op. cit. (40), p. 338.

43 There is an anecdote from Karl Pearson presenting Maxwell as a biblical literalist quoted in Smith, op. cit. (7), p. 307. This story is quite different from the other evidence we have about Maxwell's religious beliefs and outlook. I would infer that Pearson confused Maxwell's deep respect for scripture for a slavish literalism. Maxwell was certainly not averse to interpreting biblical passages (see Maxwell to Charles John Ellicott, Bishop of Gloucester and Bristol, 22 November 1876, *SLP*, vol. 3, pp. 416–8).

44 See Livingstone, Hart and Noll, op. cit. (25), particularly Bebbington, op. cit. (25); and Topham, op. cit. (25).

45 Bebbington, op. cit. (25), pp. 120–122.

46 For example, William Astore, *Observing God: Thomas Dick, Evangelicalism, and Popular Science in Victorian Britain and America*, Aldershot: Ashgate: 2001; Aileen Fyfe, *Science and Salvation: Evangelical Popular Science Publishing in Victorian Britain*, Chicago: University of Chicago Press, 2004, Bebbington, op. cit. (34), pp. 50–60, David B. Wilson, *Kelvin and Stokes: A Comparative Study in Victorian Physics*, Bristol: Hilger, 1987, Chapter 4.

47 John Hedley Brooke, 'Introduction', in Livingstone, Hart and Noll, op. cit. (25), pp. 23–29, 24–26. He of course cautions against taking too seriously the notion of such an archetype.

An important distinction to be made when thinking about evangelical science is between *natural theology* (in the sense of grounding religious truths in the natural world) and a *theology of nature* (recognition of the role of God in nature).[48] Thus, even if an individual held scripture to be primary, there could still be a robust devotional role for science. Natural reason and revelation could work together.

Thomas Chalmers, the massively influential Scottish theologian, provides an important example of how Victorian evangelicals could approach science. Early in his career he was sceptical of natural theology for all the reasons discussed above, but eventually accepted the utility of scientific knowledge for specific religious purposes.[49] His famous 1817 lectures on astronomy built on Scottish Calvinism and the Scottish Common Sense philosophy to assert both the value and the limitations of natural knowledge. Roughly speaking, his purpose was to defend Christian revelation from objections that had been brought based on the vastness of the universe, but not necessarily to convert unbelievers.[50] Such evangelical theologies of nature often critiqued Paley for not accepting the 'dysfunctional aspect of creation', and integrated visions of sin and evil.[51] Crosbie Smith points out that while Chalmers argued for a universe governed by divinely chosen laws, he emphasized both the beginning and ending of the world and its associated utter dependence on divine will.[52] In particular, the creator arranged the material of the universe in particular 'collocations' that would lead to his desired outcome.[53] As with salvation, God had bestowed certain gifts upon humanity, which could either be embraced or ignored. The action and role of God could be found in nature, but only through a lens of human sin, fallibility and complete separation from the divine.

To help place Maxwell within this tradition, it is helpful to refer to Boyd Hilton's reading of nineteenth-century evangelicalism as representing 'a shift in natural religion from *evidences* to *paradoxes*'.[54] That is, a major claim of Enlightenment natural religion was that God's benevolence and foresight could be immediately seen in the harmonies of both nature and human affairs. However, the wars, economic upheavals and political unrest in the Britain of the early decades of the nineteenth century drove many to doubt that divine governance was really so easily seen. So instead many evangelicals began to emphasize that the harmonies of nature were still present, but were hidden from view behind war and famine.[55] These were paradoxes of the sort that Hilton describes early Victorian evangelicals as grappling with: the defence of a just, beneficent God who plans ahead despite a world that seemed to be depraved, ungodly and chaotic. This emphasis on the hidden aspect of divine action was quite comfortable with the general

48 John Hedley Brooke and R. Hookyaas, *New Interactions between Theology and Natural Science*, Milton Keynes: Open University Press, 1974.
49 Topham, op. cit. (25), p. 145.
50 Topham, op. cit. (25), pp. 165–167.
51 Bebbington, op. cit. (25), pp. 128–129.
52 Smith, op. cit. (7), pp. 18–21.
53 Hilton, op. cit. (35), p. 362.
54 Hilton, op. cit. (35), p. 21, original emphasis.
55 Hilton, op. cit. (35), pp. 21–22. Also Bebbington, op. cit. (25), p. 133.

assumptions of evangelical theology. Humans were fallen, sinful and fallible and thus could not be relied upon to find the truths of the world with their own powers. God gave humans the ability to see His actions, but only if they embrace Him fully. A religious perspective was seen as necessary to properly interpret the world's disorder, just as a religious perspective was necessary to properly interpret individual human sinful behaviour.

Crucial to this theological reasoning, and also to Maxwell's interpretation of nature, was the notion of the revelation of the mysterious. The evangelical God was wholly other, and the greater truths of the world only became known to humanity through His choice in revealing them.[56] This required both an embrace of the unknown and a faith that God would eventually provide what was necessary for comprehending the unknown. Interestingly, Maxwell talked about science in precisely this way: 'I have endeavoured to show that it is the peculiar function of physical science to lead us to the confines of the incomprehensible, and to bid us behold and receive it in faith, till such time as the mystery shall open.'[57] This kind of language, from Maxwell's inaugural lecture at Aberdeen in 1856, seems somewhat awkward from a purely naturalistic view of science but was quite recognizable for evangelical Christians. Indeed, if 'physical science' were replaced with 'scripture' or 'revelation' then this passage would seem perfectly at home in an evangelical tract. He continually emphasized that the world 'conceals far more than it displays' and that one must be patient with 'mysteries within mysteries'.[58]

Maxwell's Aberdeen lecture is a rich source for seeing how this theology of nature manifested in the realm of physics:

> Is it not wonderful that man's reason should be made a judge over God's works, and should measure, and weigh, and calculate, and say at last 'I understand I have discovered – It is right and true' . . . we see before us distinct physical truths to be discovered, and we are confident that these mysteries are an inheritance of knowledge, not revealed at once, lest we should become proud in knowledge, and despise patient inquiry, but so arranged that, as each new truth is unravelled it becomes a clear, well-established addition to science, quite free from the mystery which must still remain, to show that every atom of creation is *unfathomable* in its perfection. While we look down with awe into these unsearchable depths and treasure up with care what with our little line and plummet we can reach, we ought to admire the wisdom of Him who has arranged these mysteries that we find first that which we can *understand* at first and the rest in order so that it is possible for us to have an ever increasing stock of *known* truth concerning things whose nature is absolutely incomprehensible.[59]

Note the repeated warnings against human pride and arrogance, and the evocative image of man's limited powers represented by 'our little line and plummet'. The deepest truths of nature were simply beyond our understanding, except where God allowed us to explore. As with the evangelical position on sin and redemption, our ability to know anything about the universe was just the result of God's grace in making those things

56 Hilton discusses similar approaches to science, op. cit. (35), pp. 304–314.

57 Maxwell, 'Aberdeen', op. cit. (16), p. 78.

58 Maxwell, 'Aberdeen', op. cit. (16), p. 80; and Maxwell, 'Inaugural lecture at King's College, London', *SLP*, vol. 1, pp. 662–674.

59 Maxwell, 'Aberdeen', op. cit. (16), p. 77, original emphasis.

known and available. Comprehension of nature was the result of God's free choice to set up the laws of nature such that they could be understood, not just a result of human efforts. God wanted us to learn.

Thus Maxwell's theology of nature gave him both an assurance that natural laws were uniform and also an explanation for why the world did not always look that way: seeing uniformity was divine providence, seeing complexity was intrinsic human failing. This peculiarly evangelical twist on the theology of nature had the additional benefit of avoiding a common difficulty of invoking divine action in science. Claiming divine action or design usually calls a sudden halt to scientific inquiry by declaring a phenomenon unexplainable by science and understandable only by religion, usually scripture. But Maxwell's evangelical God had planned the universe very carefully to always have lingering mysteries that humans were supposed to investigate. Mysteries were there to be uncovered and would lead to even more mysteries to solve. There was no level of explanation at which science was instructed to stop, and there was always something more to be found. Further, there was an assurance that the results of these investigations could never be dangerous to religion, because God had planned out exactly what could be comprehended and what would remain opaque. Again from the Aberdeen lecture:

> I have also thought it unnecessary to tell you that the study of the world in which we live is our obvious duty as a condition of our fulfilling the original command 'to subdue the earth and have dominion over the creatures'. Those who have raised objections to the engrossing pursuit of physical science had done so on the ground of the supposed effects of exact science in making the mind unfitted to receive truths which it cannot comprehend. I have endeavoured to show that it is the peculiar function of physical science to lead us to the confines of the incomprehensible, and to bid us behold and receive it in faith, till such time as the mystery shall open.[60]

For Maxwell, physics was an echo of biblical commandments. Pursuing deeper and deeper levels of unification was a religious task in that he was following the path God had laid down for him. God revealed truth to man in scripture and the natural world, and it was an obligation to pursue both.

The pedagogical context of the Aberdeen lecture sheds further light on what Maxwell meant when he talked about God's book of nature. The laws of nature were not just any kind of book – they were a *textbook*.[61] Maxwell's God was a teacher who wanted his students to learn all the details of the world, which He organized in such a way as to help them in their studies. Maxwell planned to lead his students through the mysteries of physical science by following the lesson plans laid out by his Creator, found through his own researches. In this way, he fused the roles of natural philosopher, teacher and evangelist by following the principles and structures of the text of Creation.

60 Maxwell, 'Aberdeen', op. cit. (16), p. 78.
61 I am indebted to an anonymous referee for this insight.

Conclusion

Nobel Prize-winner Abdus Salam called Maxwell's unification of electricity, magnetism and optics the 'prototype' for modern physics.[62] Physicists regularly draw a line from Maxwell's equations through electroweak unification to the hoped-for grand unified theory. His achievement is hailed as 'one of the great intellectual leaps in scientific history' and 'a giant leap on the path toward a simple, concise description of nature'.[63]

Salam also called Maxwell's unification 'miraculous', which is more accurate than he knew.[64] To modern physicists it seems obvious that nature must be unified – how could it be otherwise? But Maxwell saw tremendous significance in a universe where the laws of nature fit together like pieces in a puzzle. In those links he saw the existence and goodness of God, the mystery of the divine, the humility of man, and the approval of science as a Christian project. One of the foundations of modern physics, unification, was a signpost charged with religious significance for one of its founders.

Even further, Maxwell argued that this foundation was a part of an argument that modern scientists have soundly rejected – that of divine design. ID-style design arguments have real problems for the practice of science. Their claim that complex mysteries must be accepted as impenetrable barriers forbids further exploration. This 'science stopper' is a genuine obstacle: every puzzle that has ever been encountered in the history of science could have been declared to be 'irreducibly complex', and would have then been shelved as a research project. Newton was unable to understand the stability of the solar system, so he invoked, very much in the style of ID, divine intervention to restore periodically the planets' orbits. If astronomers had simply accepted this, Laplace would never have bothered to investigate further and find that there were natural laws that could ensure stability. Everything looks irreducibly complex until it has been explained. If there is one concept that makes science work, it is the idea that there is more to be learned about the natural world.

Maxwell's design argument, on the other hand, was quite different from the go-no-further claims of ID. His evangelical vision of a God who both hides and reveals the truths of nature gave him resources for dealing with the unknown. Instead of seeing irreducible complexity in every mystery, he saw a divinely ordained invitation to search farther. It was this evangelical expectation that science must always look deeper that allowed Maxwell to avoid the science-stopper problem. His variation on the design argument, based on the unity of nature, always encouraged further exploration by science.

This essay has shown that the drive to explain nature scientifically is not incompatible with theism or the design argument. Maxwell believed powerfully in the presence of

62 Abdus Salam, *Unification of Fundamental Forces*, Cambridge: Cambridge University Press, 1990, p. 40.

63 David Lindley, *The End of Physics*, New York: Basic Books, 1993, p. 41; Dan Falk, *Universe on a T-Shirt*, New York: Arcade Press, 2004, p. 86; such quotes could be easily multiplied. Margaret Morrison, *Unifying Scientific Theories*, Cambridge: Cambridge University Press, 2000, uses Maxwell's theory to examine some of the philosophical issues surrounding unification in science. For an overview of such issues see Jordi Cat, 'The unity of science', in *The Stanford Encyclopedia of Philosophy* (Fall 2007 edition) (ed. Edward N. Zalta), accessible via http://plato.stanford.edu/archives/fall2007/entries/scientific-unity.

64 Salam, op. cit. (62), p. 12.

divine action in the world, but still thought that explanations could, and should, be sought in terms of natural laws. Moving to deeper and deeper levels of unification in science was embracing God's grace in allowing humans to understand His creation.

I do not want to reduce Maxwell's physics to a solely religious argument. His theological beliefs did not replace experimental or analytical work, and it is not the case that his scientific claims were simply importations of religious ones. It is clear that there were many factors at work in this process, and other historians have documented the other philosophical, cultural, mathematical and metrological foundations of the electromagnetic theory of light. I am not suggesting that Maxwell's religious beliefs convinced him of the existence of the ether, of any particular properties of the ether, or that the ether had any specific theological role.[65] Indeed, he explicitly turned away from opportunities for such statements. Rather, his religion gave him reason to think that a given kind of pursuit (looking for unity) would be fruitful, and even theologically sanctioned. His religion and his science were not the same thing, but they were mutually supporting.

And while unification had clear religious significance to Maxwell, it was significant in a number of other contexts as well, notably the contemporary purely naturalistic cosmologies of John Tyndall and Thomas Henry Huxley. Tyndall and his allies from the 'X-Club' sought to seize control of British science and reshape it completely to fit their areligious vision. Unification was key for them as more and more phenomena came 'under the dominion of that law of causal connexion which, so far as the human understanding has yet pierced, asserts itself everywhere in nature', which would then 'sweep from the field of theory this mob of gods and demons'.[66] Crosbie Smith argues that Maxwell and the North British group prevented these Tyndallian attempts at the domination of physics.[67] In *The Science of Energy* he shows how the North British group presented themselves as an alternative scientific reform programme: improving British science did not have to mean discarding Christianity. My argument here builds on and supplements Smith. I follow him completely in framing Maxwell's physics as a defence of North British values against those of the metropolis, and that Maxwell saw close parallels between being a natural philosopher and being a minister of Christ.[68] But in addition to energy physics alone, I have here argued that the very concept of unification played a similar role. Just as Tait battled against Tyndall to make the case that energy physics supported theism over naturalism, Maxwell worked in a mindset where the unification of disparate laws pointed to the handiwork of God rather than to mindless mechanism. Within the larger community of the North British group, Maxwell had a distinctive twist on evangelicalism that provided even deeper religious dimensions to his work.

65 The ether did perform important theological functions for others, however. See Geoffrey Cantor, 'The theological significance of ethers', in Geoffrey N. Cantor and M.J.S. Hodge, *Conceptions of Ether: Studies in the History of Ether Theories 1740–1900*, Cambridge: Cambridge University Press, 1981, pp. 135–156.

66 John Tyndall, 'Address', in *Report of the Forty-Fourth Meeting of the British Association for the Advancement of Science Held at Belfast in August 1874*, London: John Murray, 1875, pp. lxxxviii, lxvii.

67 Smith, op. cit. (7), Chapters 9, 11 and 12.

68 Smith, op. cit. (7), p. 216.

In this way, unification, like energy, became a point of contest between theistic and naturalistic science. But the fact that both sides of the contest could claim it for their own leads us to a surprising end. It is often assumed that theistic and non-theistic views of nature produce wholly irreconcilable outlooks, but in practice many categories (e.g. unification) exist at an overlap between such views. Both Maxwell and Tyndall made the case that unification was inseparable from their world view and was antithetical to that of their opponents. The odd result was that both were working towards similar goals despite having completely different justifications and motivations. Foundational elements of science such as unification can be and have been justified and defended from a dizzying array of philosophical positions without restricting scientists' efforts. Maxwell saw great theological significance to his work on unification, but that was largely forgotten or ignored by subsequent generations while the work itself was still celebrated. Religion can have a powerful impact on the practice of science without creating a dogmatic category such as 'religious science' that is easily recognized as separate from 'non-religious' science. The religious beliefs and practices of a scientist can manifest in a number of explicit or subtle ways that are often in comfortable harmony with contemporary scientific practice in general.

The links between Victorian evangelicalism and science were neither obvious nor simple.[69] Maxwell's work as a religious scientist was subject to significant tension between his evangelical theology of fallen man, which demanded humility and scepticism of hypotheses, and his evangelical theology of fallen nature, which postulated a hidden divine regularity and simplicity beneath apparent chaos and complexity. This sort of tension was one of the reasons evangelicals did not always have an easy time in science. Reconciling the assumptions of evangelicalism with purposeful study of the natural world was not an easy task. But it was very productive for Maxwell: his evangelicalism allowed the unification of natural laws and the practice of science to exist comfortably within a world view based on scripture and sin.

69 For more examples of how evangelical scientists of Maxwell's generation grappled with these issues see David Livingstone, *Darwin's Forgotten Defenders: The Encounter between Evangelical Theology and Evolutionary Thought*, Grand Rapids, MI: Eerdmans Publishing, 1987.