Mechanism and Meaning:

British Natural Theology and the Literature of Technology, 1820-1840

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Abstract

As Carlyle recognized—and Arnold deplored—the nineteenth century was the 'Age of Machinery'. Increasingly ubiquitous physical things, machines were also increasingly important cultural objects. In this project, I track how the meanings of machines were constructed by an emergent 'literature of technology' and ask what cultural work those meanings accomplished. From popular expositions of steam engines to mechanics textbooks to industrial travel narratives to histories of technology, the material, literary, and generic forms of these texts constructed the 'machine' as an intelligible object of public culture, as part of nature, as passive servant to human agents, and as the product of complex development. The cultural impact of such significances reverberated beyond debates on technology to shape seemingly irrelevant discourses: these meanings were harnessed by mechanical metaphors to do work in other cultural domains from poetics to political economy to religion. As a case study, I trace how each of these meanings supported or challenged the plausibility of natural theology in the 1830s, a religious discourse built on an analogy between machines and natural objects. Drawing on often-read texts like Babbage's *On the Economy of Machinery and Manufactures* and Ure's *Philosophy of Manufactures* and lesser-read texts like the Bridgewater Treatises, Lardner's *The Steam Engine*, Head's *A Home Tour through the Manufacturing Districts*, and Whewell's *Mechanics of Engineering*, this project ultimately argues that the way technology is talked about matters.

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If the past is a foreign country, then I have been a double alien while writing this project: academically I have explored one territory of the past and personally I have learned to live and work in a country that is not my own. Any success I have achieved in these areas is due to the skill of my guides and the companionship of my fellow travelers. With financial support in the form of a Departmental Scholarship offered by the University of Kent, School of English, I arrived in the United Kingdom from the United States in September of 2009, and would have felt entirely lost without my guides, known as academic supervisors, Stephen Prickett and Vybarr Cregan-Reid. Together they have eased both the academic and personal transitions, giving helpful direction, advice, and support. My fellow pilgrims, also from around the world, Monica Mattfeld, Sarah Horgan, Declan Wiffen, and Dara Blumenthal, have kept me company and encouraged me along the way. Finally, my partner, Anthony Salvey, has kept me putting one foot in front of the other on this great adventure.

PREFACE

This project began with a Victorian children's book: Charles Kingsley's *The Water-Babies*. In the happy ending of this delightfully absurd and eclectic novel, the protagonist, Tom, grows up to be 'a great man of science, and can plan railroads, and steam-engines, and electric telegraphs, and rifled guns, and so forth; and knows everything about everything' (233-234). Reading with literary studies glasses on, I was shocked. With the often-assumed antagonism between literature and technology, especially in the Victorian period, how could a happy ending include growing up to be a maker of machines, an engineer? I turned back to the several hundred pages preceding the ending to try to understand this celebration of Britain's technological leaders. I discovered that Kingsley was not particularly critical of machines, but that he presented them as good through their centrality to metaphors of divine design. Kingsley's natural world was like machinery in certain ways, which he capitalized on to point to the divine designer of the natural world. Connecting machines with God, Kingsley rewarded Tom by making him an engineer in the image of God.

This shock suggested to me that machines do not have stable meanings, but ones that change over time. When I assumed that Kingsley as a Victorian writer saw machines as a force threatening humanity, instead he connected machines to the qualities humans shared with God. That Kingsley's celebration of engineers was related to his natural theology brought two well-known historical facts together in my mind: that the nineteenth century was both the 'Age of Machinery' (Carlyle, 'Signs' 59) and a time when natural theology was a 'common context' (R. Young 227-228) permeating social and scientific systems. These two phenomena had to be linked; the growth and celebration of technological development had to be connected to the success of natural theology's watch-maker analogies and mechanical metaphors. The story of this project is the testing and exploration of this hypothesis.

INTRODUCTION

On the sixth of October, 1829, a crowd of between 10,000 and 15,000 people gathered in a village ten miles east of Liverpool to witness one of the great spectacles of their time. According to John Francis, a historian writing two decades later:

> The adjacent country poured forth its thousands. Every class of social life sent a representative. The farmer who had anathematised it, came to wonder; the operative who could understand it, came to praise. Wherever a glimpse could be caught of the new machine, the space was filled with expectant eyes. Engineers from all quarters of the kingdom looked significantly on. The man of science interested in the dawn of a great change, awaited eagerly the result. The representative of letters was there to record the advent of a power as fruitful as his own. The Earl of Derby came to rejoice in its failure; the directors were there to enjoy its success. Many a youthful student of mechanics left his books, and many an intelligent artisan forfeited his wages to catch the first glimpse of that power which was to renew the youth of England. (1: 127-128)

The event was covered by newspapers and journals the nation over, from regionals like the *Liverpool Mercury* and *Manchester Guardian* to ones published in the metropolis like the *London Times* and the *Mechanic's Magazine*. What could motivate such an enthusiastic throng to spend all day on their feet in a relatively isolated area? A competition showcasing the newest technology on the market: the locomotive steam engine. And the people were not disappointed. On this first day of the Rainhill trials upon the newly-constructed Liverpool and Manchester Railway, George and Robert Stephenson's 'The Rocket' astonished observers by travelling at twenty-nine miles per hour. Over the next several days it bested three competitors, becoming the fastest and most reliable locomotive steam engine on the market.[1]

This fascination with new technologies was not isolated to the industrial north, but endemic to the nation during the late 1820s and through the 1830s. Opened to much fanfare in June 1832, the National Gallery of Practical Science, or Adelaide Gallery, on London's Adelaide Street, displayed new technologies to the general public and staged public demonstrations with the relatively low admission price of one shilling, the usual entry cost to

[1] On the Rainhill trials, see Carlson 218-226; Francis 1: 127-130.

a show or exhibition in the capital. The Adelaide Gallery's success begat imitators. In 1838, the Polytechnic Institution opened off Cavendish Square and persisted longer than its progenitor, even as enthusiasm for displays of technology waned in the 1840s.[2] As cultural events, then, the Rainhill trials, the Adelaide Gallery, and the Polytechnic Institution testify to the immense fascination machines had for early nineteenth-century Britons.

New-fangled technologies were not their only obsession. They were equally fascinated by religion—and the crises its institutions and their adherents experienced. Where technology had its spot in the limelight with the Rainhill trials of 1829, British Christianity produced its own 'major cultural event' (Corsi 180) with the publication of the eight Bridgewater Treatises in the middle years of the 1830s. Although sometimes dismissed and frequently ignored by scholars, the Bridgewater Treatises were nevertheless enormously anticipated and popular works of natural theology in their time.[3] Even before they appeared in print, the conditions of their publication made them a major topic of discussion: not only were they precipitated by a valuable and well-publicized £8,000 bequest left by the eccentric eighth Earl of Bridgewater and administered by the President of the Royal Society with the assistance of the Archbishop of Canterbury and the Bishop of London, but they were authored by religious, intellectual, and scientific heavy-hitters, like William Buckland, Thomas Chalmers, and William Whewell.[4] Participating in the publishing boom of the 1830s, they presented lavish evidence of design in nature, from insects to digestion to fossils to the solar system, and from a panoply of emergent scientific disciplines, including astronomy, geology, biology, entomology, zoology, psychology and sociology, anatomy and physiology, and chemistry. They first appeared between 1833 and 1837, but by the end of the 1840s there were over 60,000 printed copies and more than 120 reviews in 40 different periodicals.[5] They were not cultural anomalies: the Bridgewater Treatises were buttressed at their logical and theological foundation by a number of philosophical treatments of natural theology, some by celebrities like Henry Brougham and Charles Babbage.[6]

Both of these early nineteenth-century cultural phenomena, natural theology and technology, have received ample scholarly attention—yet they are almost always considered

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[2] On galleries of practical science, see Morus, *Frankenstein's* 70-98.
[3] For dismissals, see Desmond and Moore 213, 219; R. Young 2, 32, 189. On anticipation for the Bridgewater Treatises, see Topham, 'Beyond'; on their pervasive presence in adult education and working man's libraries, see Topham, 'Science and Popular'.
[4] On the controversial selection of the Bridgewater authors, see Brock; for a full publication history, see Topham, '"Infinite"'; for their participation in the publishing boom of the 1830s, see Topham, 'Beyond'.
[5] Topham, 'Beyond' 241, 249.
[6] For scholarly recognitions of natural theology's cultural power, see Eddy and Knight xxviii; Fyfe, 'Reception' 321-322; D. Thompson.

in isolation from one another. For what do religion and technology have to do with each other? While this question has been taken up for other centuries, especially our own, it has been mostly neglected for the nineteenth.[7] The links that have been identified are mostly sociological: first, the empirical fact that evangelicals led the factory reform movement, and second, the interpretive thesis that industrialization plus urbanization led to secularization, a now-disputed interpretation.[8] But outside the sociological questions of whether people attended church or exactly how much impact the reformers' evangelicalism had, there are a myriad of questions and frames through which the relationship between technology and religion could be explored. One could ask how technology shaped religion or how religion shaped technology and ask these questions within the disciplinary structures of religious history or the history of technology. One could ask about the religious beliefs of engineers and mechanics or could ask about the impact of factory work on the religious experience of the working class. But moving away from the biographical and sociological, this project will focus on the cultural dimensions of the relationship between technology and religion, asking how the cognitive content of religion, specifically of natural theology, related to technology.

Early nineteenth-century Christianity itself identified a link between natural theology and its technological context: natural theology's central rhetorical move, the design analogy, implicitly depended on culturally-shared understandings of the way humans made things (engineering) and of the things they made (technology). William Paley opens his *Natural Theology* (1802) with this analogy's most famous statement:

> In crossing a heath, suppose I pitched my foot against a *stone* and were asked how the stone came to be there, I might possibly answer, that, for any thing I knew to the contrary, it had lain there for ever: nor would it perhaps be very easy to shew the absurdity of this answer. But suppose I had found a *watch* upon the ground, and it should be enquired how the watch happened to be in that place, I should hardly think of the answer which I had before given, that, for any thing I knew, the watch might have always been there. Yet why should not this answer serve for the watch, as well as for the stone? Why is it not as admissible in the second case, as in the first? For this reason, and for no other, viz. that, when we come to inspect the watch, we perceive (what we could not

[7] For philosophical work on technology and theology, see Borgman; Newman; Pattison. For historical work on technology and religion in the medieval period, see L. White; and from the Renaissance onwards, see Noble.

[8] For foundational scholarship on industrialization as leading to secularization, see Gilbert. For adoptions, extensions, and revisions of this claim, see Borgman; the essays in McLeod, *European*. For recent 'optimist' views which question the negative impact of urbanization on British religiosity, see C. Brown; Cox.

> discover in the stone) that its several parts are framed and put together for a purpose, e. g. that they are so formed and adjusted as to produce motion, and that motion so regulated as to point out the hour of the day; that, if the several parts had been differently shaped from what they are, of a different size from what they are, or placed after any other manner, or in any other order, than that in which they are placed, either no motion at all would have been carried on in the machine, or none which would have answered the use, that is now served by it. (7)

After lengthily describing the parts of this found watch, Paley concludes that 'this mechanism being observed … the inference, we think, is inevitable; that the watch must have had a maker; that there must have existed, at some time and at some place or other, an artificer or artificers who formed it for the purpose which we find it actually to answer; who comprehended its construction, and designed its use' (8). Using a machine as the foundation of his analogy, Paley tethered natural theology to its technological context: by drawing on machines and engineering for his figurative language and his conceptual metaphors, Paley bound the two phenomena together.

Thus, considering the industrial context of nineteenth-century natural theology, my argument is that natural theology was plausible and popular in the 1830s because its central mechanical metaphor—its analogizing of nature to human-made technologies—was appealing to an audience fascinated with technology. More than this, a new literature of technology constructed meanings of machines which fuelled the mechanical design analogy, the engine of 1830s natural theology. The project will first argue for the mechanical shape of early nineteenth-century natural theology then will ask what meanings of machines made the design analogy cognitively powerful in the 1830s and how those meanings were created. It will then track how various genres of the 'literature of technology' constructed specific meanings of machines and how natural theology both depended on and responded to those meanings. Thus, although the link between religion and technology could be approached through religious history or through technological history, I am instead approaching it from a literary perspective, connecting technology and religion through their literatures and literary forms, through their expression in and construction by texts.

The prominence of mechanical metaphors in natural theology seems like it would compel an awareness of natural theology's enabling technological context on historians. But this has not been the case. Our own historiographical traditions indicate why. Ironically, a major cause has been the observation-turned-assumption that natural theology was a parasite dependent on the mechanistic science of the scientific revolution, dying with its host around 1800.[9] Conceiving and describing the natural world primarily through mechanical metaphors, mechanistic science did natural theology's dirty work by demonstrating design in nature. All natural theology had to do was argue from that obvious mechanical design to God. But this fairly accurate conflation of natural theology with the mechanistic worldview dominating the seventeenth and eighteenth centuries creates a major distortion in the picture of nineteenth-century natural theology: it fails to acknowledge, let alone account for, the resurgence of natural theology three long decades into the nineteenth century. Since the 1980s, work by John Hedley Brooke and then Jonathan Topham, among others, has corrected this misprision by highlighting both the existence and importance of the natural theology of the 1830s. But where earlier scholars related seventeenth- and eighteenth-century natural theology to technology through the ossified metaphors of mechanistic science, recent scholars have ignored the technological metaphors and context of 1830s natural theology altogether. In this project, I would like to combine the two approaches, studying the natural theology of the 1830s by re-forging its link to technology through the metaphors and analogies which pervade the Bridgewater Treatises and their philosophical cohort.

Against historical incredulity about the persistence of natural theology and of mechanical metaphors, the first chapter, 'The Divine Mechanic: Mechanical Metaphors and the Natural Theology of the 1830s', argues that mechanical metaphors continued to conceptually structure the natural theology of the 1830s and therefore that its plausibility was dependent on the meanings of machines. Partly introductory, it first outlines scholarship on natural theology, engages theories of metaphor, and briefly summarizes the history of mechanical metaphors in natural theology before 1800. It then traces the usage and importance of mechanical metaphors in the Bridgewater Treatises, arguing that these metaphors constituted the logic as much as they determined the language of design. Also partly introductory, the second chapter, 'Understanding Machines: The Literature of Technology, the Steam Engine, and Comprehensibility, argues that the meanings of machines which mechanical metaphors captured were constructed by a 'literature of technology' emergent in the 1820s through the 1840s. After engaging with thing theory and modern genre theory, it offers a brief history and taxonomy of the 'literature of technology', before honing in on a single meaning of machines that made natural theology possible: intelligibility. The chapter argues that the intelligibility of machines and of the natural world

[9] For scholars grouping natural theology with mechanistic science, see Gascoigne 223; F. Gregory 370; Jacob, 'Christianity' 249-253; Maurice and Mayr ix; Mayr, 'Mechanical' 4.

were essential to design's plausibility—for if people could not comprehend how something worked, they could not see design in it. Implicitly answering this need, a genre of 'popular technology' in the 1820s-1840s formulated steam engines as intelligible objects of knowledge by creating and disseminating a language through which they could be discussed. Buttressing design's psychological foundations, these texts shaped how the argument from design proceeded in the 1830s. The Bridgewater Treatises internalized the explanatory methods of popular technology, focusing on how the parts of the animal body fit together.

Chapters three through five largely follow the pattern of chapter two by exploring how specific genres of the literature of technology constructed the meanings of machines on which natural theology depended. Chapter three, 'Taxonomy, Topography, and the Picturesque: Industrial Travel Narratives and the Natural Machine', considers how an essential point for the design analogy was established: that the natural world is similar to humanly-designed objects. Blending the natural and mechanical, texts of industrial tourism naturalized machines by presenting factories as part of the natural landscape through topographic and picturesque visual modes and by classifying machines into a natural history continuous with the order of nature. In this case, the literatures of natural theology and of technology had a symbiotic relationship, mutually supporting and influencing the presentation of order in the natural world. Taking up another positive meaning of machines, chapter four, 'Of Minds and Machines: Mechanics Textbooks, the Laws of Nature, and Divine Action', argues that the increasing mathematization of machines in mechanics textbooks and its accompanying emphasis on human control facilitated natural theology's shift toward evidence drawn from natural law. Both genres faced a similar objection: industrial machines threatened the agency of men while the laws of nature threatened the agency of God. Describing machines as subject to the principles and laws of nature knowable by humans, technical literature on mechanics presented humans as in control of machines through that knowledge. Natural theology borrowed this reconciliation of minds and machines by appealing to the mind behind laws in order to integrate an active God into a law-bound world. Finally, where chapters two through four track the support literatures of technology provided to natural theology, the fifth chapter remains sensitive to the multiple and changing meanings of technology that damaged the plausibility of natural theology. 'Vestiges of the Natural History of Invention: Histories of Technology and Historicizing Design' traces how histories of technology and invention historicized and problematized invention and the development of technology. No longer the product of genius, machines were the product of trial-and-error. This undermined the design analogy by suggesting that design in nature could also be the product of trial-and-error over time—and fed into an evolutionary view of nature's history.

Altogether, the project is like a Victorian Realist novel: it is a multi-plot story held together by a metaphor. Structurally, its chapters are dialogic, alternating discussions of natural theology with discussions of the literature of technology, often first framed by an objection to natural theology that indicates a meaning for machines which design's believability required. Historically, it has multiple narratives. For religious history, it tells the story of natural theology's plausibility in the 1830s, accounting for its popularity. For technological history, it tells the story of how literature engaged in the construction of meanings for machines. For intellectual history, it tells the story of how mechanical metaphors continued to be prominent in the early nineteenth century because they evolved with the meanings of machines. This third story is the weft that connects the warp threads of the other two. Philosophically, the project deploys multiple theoretical approaches and asks multiple questions. It uses thing theory, genre theory, and conceptual metaphor theory while fusing new formalism with new historicism. Located in between academic disciplines, it asks about the meanings of machines, about religious plausibility, about the appeal of mechanical metaphors, about how to characterize nineteenth-century British Christianity, and about the relationships of literature and technology and of technology and religion.

But the foundational questions of this project are these: what does technology mean? How is that meaning constructed? What does that meaning mean—or what cultural work does that meaning accomplish? My basic conviction in answering these questions is that the way technology is talked about matters—that words play an essential role in translating technologies into meaningful cultural objects. The historicity of this project is obvious, reflected in my specific claims about early nineteenth-century technology and religion. But it is also an essentially literary one. Technology never comes to us directly or immediately, but always, like sexuality or nature, packaged in discourse—in words and literatures. If we take 'literature' to mean a timeless work of art with a certain quality of literariness, then this project is not about literature at all. But if we take 'literature' to mean what is put into words—often printed and published—then this project is about literature because it is about the value of those words and of the ways they are put together. Most studies of 'literature' take the narrower definition, considering the value of the words of George Eliot, John Milton, T.S. Eliot, Mark Twain, Salman Rushdie, or Toni Morrison. But the same thing can—and should—be done with words of a less literary nature. It should be done because all words matter, not just the literary ones. By exclusively focusing on the literary, we run the risk of suggesting, by omission, that non-literary expression does not matter. But more specifically to my project, we need to be aware that the way we package technology in words matters for our lives, for our ideas, and for our future. By tracing the way words about technology mattered in the nineteenth century, I hope to raise awareness of the way we talk about technology today, from toilets to nuclear power stations to smartphones.

CHAPTER 1

The Cosmic Mechanic: Mechanical Metaphors and Early Nineteenth-Century Natural Theology

It is a commonplace academically assumed that the world was understood through mechanical metaphors before 1800 and through organic metaphors after 1800, or thereabouts. Largely established by worldview-focused intellectual historians in the 1950s and 1960s like Alexander Koyré, Arthur Koestler, and A.O. Lovejoy, and by M.H. Abrams's literary history in *The Mirror and the Lamp* (1953), this view continues to haunt the historiography and pedagogy of science and of literature today. When applied selectively to certain cultural areas, it seems to be right; it seems to be useful for describing some ideas, movements, and changes. The mechanistic astronomical science of Descartes and Newton was replaced by the science of biology with its focus on life and the dynamic qualities of nature, represented in Darwin's 'great Tree of Life' (274). In literature, 'Romanticism' reacted against mechanicism, the Enlightenment, and rigid poetic neoclassicism like Alexander Pope's. It turned to nature in its subject matter, as its style, and for its model of the world.[1] The ire which the great nineteenth-century sages directed at mechanicism seems to substantiate organicism's triumph. In his 1829 essay 'Signs of the Times', Thomas Carlyle complained that his was 'the Age of Machinery, in every outward and inward sense of that word; the age which, with its whole undivided might, forwards, teaches and practices the great art of adapting means to ends' (59). He denounces the mechanical philosophy of mind, matter, and man held by Adam Smith, William Paley, Jeremy Bentham, and Robert Owen, who 'by arguing on the "force of circumstance," … have argued away all force from ourselves' (79). For Carlyle, the inward life 'cultivated on such principles … is found to yield no result' (66). Carlyle's venerable disciples included Charles Dickens, John Ruskin, and Matthew Arnold: Dickens's *Hard Times* illustrates the disaster that ensues when a child's education is governed by mechanical metaphors. At the broad-brush historical level, then, the historical generalization that organic replaced mechanical metaphors seems fairly helpful for understanding—or at least communicating—the worldview, ethos, *episteme*, or *zeitgeist* of the nineteenth century.

[1] Leading the charge in 1927, A.N. Whitehead suggested that Romantic literature was a 'reaction' to the mechanistic scientific outlook of the seventeenth and eighteenth centuries (93-118). Recently, Tresch has contradicted the opposition between organicism and mechanism historically while Canguilhem has done so philosophically.

However, there is a problem with assuming that the popular majority preferred organicism and repudiated mechanicism in a country where thousands turned out to watch the Rainhill trials of the railroad steam engine in 1829 and tens of thousands attended the Great Exhibition, with its magnificent machine hall, in 1851. The disappearance of mechanical metaphors as central conceptual metaphors in nineteenth-century Britain seems implausible when the machine was increasingly interesting and therefore increasingly rich in meaning. The view that mechanical metaphors faded around 1800 fails spectacularly to notice, let alone account for, the continued appeal of mechanical metaphors in the early century. Nineteenth-century natural theology has been a major casualty of this view, its immense popularity often ignored in the historical record. Lashing natural theology tightly to pre-1800 mechanistic science through its central mechanical and design metaphors, the traditional narrative suggests that natural theology went down with the ship.

Yet the narrative of mechanicism's recession which justifies the account of natural theology as atrophying around 1800 makes many mistakes. First, it uses scientific conceptual metaphors to characterize an entire culture, ignoring the fact that metaphors may be meaningful in the broader culture but not in science or vice-versa. Second, it creates a paradigm in which any nineteenth-century natural theology can only be accounted for as anachronistic or culturally irrelevant. Third, it assumes that natural theology was a monolithic, homogeneous, and static enterprise. This is especially evident in the treatment of nineteenth-century natural theology as anachronistic, mindless repetition of its eighteenth-century predecessors, with Paley's *Natural Theology* becoming the intellectually-weak yet pervasive residue awaiting destruction as Darwin's straw man.[2] Not only does it see natural theology as monolithic, but it sees mechanical metaphors also as monoliths, implicitly ossifying the relationship between natural theology and mechanical metaphors. Thus, its historiographical assumptions make this view constitutionally insensitive to any internal changes in natural theology and to any external exigencies for those changes.

As a correction, I want to break the bond between natural theology and mechanical metaphors only to put them back together, and in doing so to remodel their relationship by recognizing the flexibility and dynamism of both. Beginning this project, this chapter asks

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[2] As anachronistic, see Desmond and Moore 213; Odom 536; R. Young 2, 189. As static, see R. Young 126-163. As Darwin's straw man, see Dijksterhuis 491; Gascoigne 244-245; Gillespie, 'Divine'; Mayr, 'Mechanical' 2; Odom; R. Olson 6; Wallace 9.

Some nineteenth-century natural theology *was* anachronistic: John Kidd's Bridgewater Treatise, *On the Adaptation of External Nature to the Physical Condition of Man* (1833), assumes the great chain of being (2-10) and the harmony of nature (52, 246) and integrates classical sources into modern science, listing the similarities between Aristotle and Cuvier in an appendix.

if—but really how—metaphors and analogies drawn from engineering and machines continued to function within the natural theology of the 1830s. At its core, the chapter argues that natural theology continued to depend on metaphors and analogies that drew on machines and engineering, but that these metaphors and analogies were different from those in mechanistic science. In dismantling and then reassembling an old relationship, this chapter makes two claims, one about mechanical metaphors and one about natural theology. Concerning mechanical metaphors, it will build on recent metaphor theory to argue that machines and engineering metaphors change over time in how they work, what work they do, and what meanings they enable. It will use the Bridgewater Treatises and their flanking philosophies of natural theology to explore the myriad functions of mechanical metaphors, but also how they differed from the universal cosmological metaphors of earlier mechanistic science. Concerning natural theology, my claim is that just as natural theology persisted beyond the emergence of new modes of science, so did its conceptual and linguistic dependence on metaphors and analogies drawn from machines and engineering persist beyond the decline of mechanistic science. But without the frame of mechanistic science, the affiliation between natural theology and mechanical metaphors took on new formulations. For mechanical metaphors continued to be used in natural theology because they continued to be useful with an audience fascinated by technology. I conclude that the meanings of man-made contrivances founded, shaped, and fulfilled the design analogy as a conceptual metaphor structuring thought itself. Limitedly, mechanical metaphors persisted in natural theology. Expansively, natural theology persisted because of mechanical metaphors. In making these two historical claims about mechanical metaphors and natural theology, this chapter will lay the historical and methodological foundation for the following four chapters about specific meanings of machines and how the technological design analogy harnessed them for natural theology.

It will first define what natural theology is (or was), summarize what other scholars have said about it as a historical phenomenon and how they have approached it, and introduce my own understanding of and methodological approach to natural theology. Second, it will go on to discuss the design analogy and its relationship to mechanical metaphors through recent metaphor theory. Third, it will trace the history of design's relationship with mechanical metaphors. And finally, it will establish the presence and shape of mechanical metaphors in 1830s natural theology.

Approaching Nineteenth-Century Natural Theology

Natural theology is hard to define. Approached from numerous disciplinary and methodological perspectives within philosophy, theology, history, and the panoply of scientific disciplines, it is both a theological or philosophical system and a historical phenomenon. Two recent essay collections, the *Blackwell Companion to Natural Theology* (2009) edited by William Lane Craig and J. P. Moreland and the *Oxford Handbook of Natural Theology* (2013) edited by Russell Re Manning, offer significantly divergent understandings of it.[3] An editorial pluralist, Re Manning refuses to specify a definition for the *Oxford Handbook*, letting his essayists do it individually.[4] What emerges is an extremely broad view of natural theology as thought about God sourced in human reason. A number of the authors recognize, however, that it has 'narrower' and 'broader' definitions.[5] Broadly, it is philosophical thought about God; narrowly, it is 'the attempt to prove theological ideas based on empirical observation of nature' (Frazier 167) or 'arguments for the existence of God' (Griffin 276). The narrower understanding is adopted by Taliaferro in introducing the *Blackwell Companion*. While he defines natural theology as 'the practice of philosophically reflecting on the existence and nature of God independent of real or apparent divine revelation or scripture' (1), he quickly aligns it with arguments for God's existence. Yet even this tightening does not stanch natural theology's diffuseness. The *Blackwell Companion* presents a variety of natural theological arguments: the design, moral, cosmological (Leibnizian and *kalam*), and ontological arguments, as well as arguments from consciousness, reason, evil, religious experience, and miracles, each with their own historical phases of popularity and eclipse.

Both collections implicitly value natural theology because it is a body of philosophical thought current today. But one of today's foremost natural theologians, Alister McGrath, suggests that natural theology is 'a conceptually fluid notion' (15) that also must be approached historically. Dynamically changing, natural theology took on different forms and was perceived through different definitions at different times.[6] In the early nineteenth

[3] Perhaps one source of the difference can be found in the relative goals of the editors. Religious leaders, Craig and Moreland hope to demonstrate the academic viability of natural theology today, while Re Manning presents natural theology from a number of approaches, including historical, philosophical, theological, scientific, and cultural.
[4] Re Manning, 'Introduction'.
[5] Anderson 354-355; Bennett-Hunter 552-553; Frazier 166-167; Griffin 276; Manson 295.
[6] McGrath provides his own history of natural theology through time. For medieval definitions, see A. Hall; early modern, see Mandelbrote, 'Early'; nineteenth-century, see Eddy, 'Nineteenth'; twenty-first-century, see the essays in Re Manning, *Oxford*.

century, ‘natural theology’ was a category for theologians and laymen alike, with a limited, if diffuse, referent different from twenty-first-century definitions. This section will introduce natural theology as a nineteenth-century historical phenomenon and articulate my own historicist approach to it by engaging established scholarship on it. Understood as rational arguments for God built on evidence from nature (Brooke and Hooykaas 8), it was defined in the full title of Paley’s seminal work: *Natural Theology, or the Evidence of the Existence and Attributes of the Deity, collected from the appearances of nature*.[7] Paley thus summed up the natural theological enterprise of his British predecessors, codified it for his contemporaries, and delineated it for his immediate successors.[8] Three decades later, the authors of the Bridgewater Treatises implicitly assumed Paley’s popular and ubiquitous definition, for his successors could ‘imitate, alter, or reject, but not ignore’ him (Lemahieu 154).[9]

Early nineteenth-century natural theology took on a number of shapes, noticed by historians. Most broadly, it was a worldview manifest in what Topham calls a ‘discourse of design’ invoked across a range of disciplines by a range of authors and speakers, including naturalists, philosophers, politicians, and theologians.[10] But design as ubiquitous language must be distinguished from natural theology as a distinct body of thought.[11] Where the language of design could serve ‘simply as an affirmation of trust’, texts of natural theology often gave design ‘a demonstrative, apologetic’ function, according to John Hedley Brooke, nineteenth-century natural theology’s foremost historian (‘Between’ 53). It thus differed

[7] Morrison drew my attention to the definition embedded in Paley’s title (152).
[8] For the influence and publication history of Paley’s *Natural Theology*, see Fyfe, ‘Publishing’, ‘Reception’. Published in 1802, it went through twelve editions by 1809, with twelve more between 1816 and 1822, plus a major updated and illustrated republication in 1826 (Fyfe, ‘Publishing’; Eddy and Knight xxiv-xxvi). Within 15 years, around 15,000 copies had been sold and as of 2002, a full fifty-seven editions had been published in Britain alone (Fyfe, ‘Publishing’, ‘Reception’). Continually remade by publishers to fit the changing culture, it retained its influence across the nineteenth century, beginning as a work of ‘gentlemanly natural theology’, then doing a stint as a science textbook, and finally becoming a classic of Christian apologetics (Fyfe, ‘Publishing’). Even Darwin’s evolutionary theories evolved out of a Paleyan structure (Ospovat, *Development*; von Sydow). Yet Paley’s popularity is downplayed by some, see Desmond and Moore 85-86; Topham, ‘Science, Natural Theology, and the Practice’ 58; R. Young 189.
[9] Their introductory and concluding comments, coupled with their treatment of their subjects, reveal an assumed definition of natural theology in line with Paley’s, see Chalmers 1: 2, 4, 13; Prout ‘Introduction’; Whewell, *Astronomy* 2-3. Of the philosophers of natural theology, Powell implies the definition (117-118, 205) and Crombie neglects it, while only Crabbe and Brougham offer specific definitions, ones slightly broader than the understandings implied in the Bridgewater Treatises (Crabbe vii-viii; Brougham 5-6, 9-10). For the Bridgewater authors’ dealings with Paley, see Bell, *Hand* x; Buckland 1: viii, 107, 135, 309, 583; Chalmers 1: 23-24, 249, 2: 98-201; Kidd 104; Prout 9-10; Roget 1: ix, 2: 67.
[10] As a culturally-pervasive worldview in the early nineteenth century, see R. Young 126-163. On the natural theology of scientists, see Brooke, ‘Religious Belief’; and of sanitation reformers, see Hamlin. For the ‘discourse of design’, see Topham, ‘Science, Natural Theology, and the Practice’ 38. Similarly, Eddy notices ‘volitionally charged words’ in a variety of nineteenth-century discourses and lists synonyms for natural theology (‘Nineteenth’ 101, 100).
[11] Topham, ‘Science, Natural Theology, and the Practice’ 38. Jager ignores design invoked as a ‘kind of sensibility’ to pursue natural theology as a theological system (2).

from 'theologies of nature', which were concerned with the broad religious value and meaning of nature rather than with its specifically apologetic value (Brooke and Hooykaas 8).[12] Instead, natural theology proper was a distinct theological system embodied in a distinct genre, 'a collection of texts that engage[d] recognisably similar subjects in a common manner' and drew on a self-conscious historical precedent (Brooke and Cantor 179) (Table 1.1).[13] While natural theology as a body of thought was expressed in these texts, their collection into a genre shaped what natural theology as a general category was perceived to be. Brooke's successor, Jonathan Topham, corroborates this approach by treating natural theology as a genre through the methodology of his book and reception history.[14] With Paley's *Natural Theology* as its figurehead, the genre consisted of British and mostly-

		Table 1.1: Natural Theology as Genre in the Long 1830s, Selected Texts	
Date	**Author**	**Title**	**Type of Text**
1829	Alexander Crombie	*Natural Theology: Or Essays on the Existence of Deity, of Providence; on the Immortality of the Soul; and a Future State*	Philosophy
1833	John Kidd	*On the Adaptation of External Nature to the Physical Condition of Man*	Applied (Bridgewater Treatise)
1833	Charles Bell	*The Hand: Its Mechanism and Vital Endowments as Evincing Design*	Applied (Bridgewater Treatise)
1833	Thomas Chalmers	*On the Power, Wisdom, and Goodness of God as Manifested in the Adaptation of External Nature to the Moral and Intellectual Constitution of Man*	Applied (Bridgewater Treatise)
1833	Henry Fergus	*The Testimony of Nature and Revelation to the Being, Perfections, and Government of God*	Applied
1833	William Whewell	*On Astronomy and General Physics Considered with Reference to Natural Theology*	Applied (Bridgewater Treatise)
1834	William Prout	*Chemistry, Meteorology, and the Function of Digestion Considered with Reference to Natural Theology*	Applied (Bridgewater Treatise)
1834	Peter Mark Roget	*Animal and Vegetable Physiology Considered with Reference to Natural Theology*	Applied (Bridgewater Treatise)
1834	William Kirby	*On the History, Habits, and Instincts of Animals*	Applied (Bridgewater Treatise)
1835	Henry Brougham	*A Discourse of Natural Theology*	Philosophy
1837	William Buckland	*On Geology and Mineralogy Considered with Reference to Natural Theology*	Applied (Bridgewater Treatise)
1837	Charles Babbage	*Ninth Bridgewater Treatise*	Philosophy
1838	Baden Powell	*The Connexion of Natural and Divine Truth: Or, the Study of the Inductive Philosophy Considered as Subservient to Theology*	Philosophy
1840	George Crabbe	*An Outline of a System of Natural Theology*	Philosophy

[12] For historical studies focusing on theologies of nature, see Astore; Fyfe, *Science*; Lightman, *Victorian* 39-94. Philosophically, this distinction is difficult to maintain because thought about the natural world and thought about God have been largely inseparable in the West (Watts, 'Natural' 476).
[13] Yet Brooke largely treats natural theology as a worldview.
[14] Topham, 'Beyond', '"Infinite"', 'Science and Popular', and 'Science, Natural Theology, and the Practice'. Eddy sees it as both an argument and as a genre including 'formal treatises … but also textbooks, sermons, and autodidact literature' ('Nineteenth' 109), focusing on the latter three and the 'pedagogical power of natural theology' (112, 109-113).

Christian books containing arguments for God's existence built on evidence from nature funnelled through the design argument.[15] The Bridgewater Treatises both instantiated and fulfilled this perception, making the genre real for these historical actors. The importance of its generic status is not in a list of formal features or shared content, but in the perception, shared by its readers and writers alike, that it was a category, a coherent body of thought represented in a genre. Thus I will approach natural theology not as a vague worldview but as a perceived body of thought manifested in and represented by a genre which included both the Bridgewater Treatises and the philosophies of natural theology which buttressed them.

In the vast field of nineteenth-century studies, the path of natural theology's development, popularity, and resilience was rarely traced until recently. In the 1980s, its scholarly recovery began where much scholarship does: with the rejection of dominant views, in this case rejection of the assumption that nineteenth-century natural theology was either non-existent or it was anachronistic, static, and homogeneous. A review of scholarship in this now strong sub-field, especially within the history of science, will both ground my project and serve as a detailed recapitulation of the history of 1830s natural theology. Challenging the thesis of an inherent conflict between science and religion in nineteenth-century Britain, John Hedley Brooke, 'the slayer of the "conflict thesis"' (Dixon 1), began natural theology's recovery by using it as his primary evidence. He showed that natural theology persisted, even flowered, as a worldview, discourse, and genre in the early nineteenth century largely because it was useful in a range of social, political, psychological, and theological ways.[16] Beyond apologia, natural theology served promotional, defensive, mediating, unifying, political, and explanatory functions: it promoted science by assuaging fears, defended both Christianity and science from scepticism, mediated between denominations through 'common ground', unified the interests of scientific clergymen or Christian scientists, intervened in politics, and explained the natural world and its details.[17] Other scholars have fleshed out the picture by evaluating these functions for specific people, sciences, institutions, and constituencies. Religiously, natural theology served 'as a source of edification, to evoke a sense of wonder, to confirm an existing faith', to convince the ambivalent, to defend the study of nature for Christians, to 'control deviancy within a specific

[15] As distinctively British, see Brooke, 'Why'. On the presence of natural theology in other religious traditions and formulations, see Craig and Sinclair; Kleeberg; Morrison.
[16] Brooke, 'Between' 54, 'Indications' 149-150, 'Natural Theology and the Plurality', 'Natural Theology of the Geologists', *Science* 192-225, 'Scientific Thought'; Brooke and Cantor 27, 153-156.
[17] Brooke, 'Indications' 149-150, *Science* 210-216.

religious tradition', and to establish common ground for missionaries.[18] But, most importantly, it defended the Church by the 'minimising of doctrinal differences and the defence of science against religious opposition'.[19] Politically, 1830s natural theology worked against the instability created by agitation for reform and supported the established economic, social, and political systems by creating common ground between various parties, continuing to support political hegemony as it had in earlier centuries.[20] Scientifically, natural theology mediated between science and religion, motivated science, created common ground between scientists of various religious traditions through the 'discourse of design', and justified science to religious detractors.[21] Concerning the content of science, natural theology responded to specific crises brought on by developments in geology and physiology; it constituted 'much of the style and rhetoric of scientific communication' as well as providing 'more general' concepts like 'final cause, design, law, miracle and Providence'; it 'provided a context for significant discussion of the methodological and epistemological features' of scientific knowledge; and it served as a framework through which to reinterpret and repackage dangerous French theories for safe British consumption.[22] Even when not stated, natural theology continued to shape science as an assumption and motivation through the century.[23] Educationally, natural theology played an important role in packaging science for the 'public', becoming one of the early forms of the popular science genre and allowing its writers to battle radical working-class thinkers for the minds of the 'public'.[24] Topham has called it 'safe science' because it was morally, socially, and politically benign reading for multiple constituencies.[25] Its usefulness indicates that natural theology not only existed in the

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[18] Brooke and Cantor 153.

[19] Brooke, 'Natural Theology of the Geologists' 46; also, 'Indications' 149.

[20] For natural theology as a response to political instability, see Brooke, 'Indications' 149-150; Brooke and Cantor 27; Morrell and Thackray 229. For natural theology's conservative support of hegemony, see Brooke and Cantor 158-159; Gascoigne; Jacob, 'Christianity'; Mayr, *Authority*. But it could also 'be used as a means of altering as well as of shoring up the established order' (Gascoigne 240).

[21] As mediating, see Brooke, 'Natural Theology of the Geologists'. As motivating, see Morrell and Thackray 227. It also motivated mathematics, see Daniel Cohen. As creating common ground, see Astore 51; Morrell and Thackray 227-229. As justifying, see Brooke, 'Natural Theology of the Geologists' 43-44; F. Turner, 'Victorian' 92. Morrell and Thackray trace these functions in the early meetings of the British Association for the Advancement of Science.

[22] As responding to crises, see Corsi 50. As constituting the style and content of science, see Brooke, 'Religious Belief'; J. Smith, 'Philip'; Topham, 'Science and Popular'. As philosophical frame for science, see Yeo, 'William'. As repackaging dangerous science, see Brooke, 'Scientific Thought'.

[23] Brooke, 'Religious Belief'; Fyfe, 'Reception'; Gillespie, 'Preparing'. On the fading of design as an overt resource for scientific explanation over the century, see Gillespie, 'Preparing'; Ospovat, 'Perfect'.

[24] As popular science, see Brooke, 'Religious Apologetics', 'Why' 76; Brooke and Cantor 156-157; Fyfe, 'Publishing'; Fyfe and Lightman, 'Science' 7-13; Lightman, *Victorian* 39-84; Topham, 'Publishing', 'Science and Popular'; F. Turner, 'Victorian' 372. On natural theology's broader educational usefulness, see Eddy, 'Nineteenth' 109-113.

[25] Topham, 'Science and Popular Education' 404.

early nineteenth century, but it was also made culturally relevant by those using it, correcting assumptions about its non-existence or anachronism.

Theses claiming natural theology's nineteenth-century homogeneity and reification have also been upset by the work of Brooke and his successors. Itself a product of the nineteenth century, belief in natural theology's homogeneity was given its last major statement by Robert M. Young, whose *Darwin's Metaphor: Nature's Place in Victorian Culture* (1985) claimed that a 'relatively homogeneous and satisfactory natural theology, best reflected' in Paley served as the 'common intellectual context' fractured by or with Darwin's *Origin of Species*.[26] Brooke worked against this 'popular image of natural theology as an essentially static, autonomous and monolithic set of presuppositions' by demonstrating the diversity and variety of natural theology in the early nineteenth century.[27] He hammers home both its diachronic and synchronic diversity—that it changed through time and that it existed in a number of different forms at any one time. For example, he outlines four types of teleological argument in the nineteenth century ('Between'), comments on the 'fundamental divergences of strategies within natural theology' ('Natural Theology and the Plurality' 221), and notices its 'diversification … rather than demise' prompted by science between 1800 and 1850 (*Science* 220). This historical pluralisation has been wholeheartedly accepted by subsequent scholars, who have chronicled a profusion of natural theologies in the early nineteenth century according to textual type, stated purpose, actual function, academic affiliation, evidential type, style, region, audience, scientific discipline, and denomination, incompletely listed.[28]

[26] R. Young 227-228, but see entire chapter (126-163).

[27] Brooke, 'Natural Theology and the Plurality' 221. Although R. Young attempts to show how Brooke's ideas do not contradict his own (161-163), the two approaches have continued to be perceived as opposed. A student of Brooke's, Topham actually writes specifically against the idea of a 'common context', see 'Beyond'.

[28] For the impact of Brooke's 'complexification' technique on the historiography of science and religion, see Dixon. On stated purpose, see Brock; Topham, 'Science and Popular' 404. On actual functions, see the previous paragraph. For academic affiliation, see Maas. For educational functions, see Eddy, 'Nineteenth'; Topham, 'Science and Popular'. Evidential types will be discussed in the final section of this chapter, but see Corsi. For style, see J. Robson. For regional attitudes to natural theology, particularly Scottish, see Astore 49; Baxter; Rice; Topham, 'Science, Natural Theology, and Evangelicalism'. For the audiences of natural theology, see Topham, 'Beyond'; 'Science and Popular'.

For Anglican natural theology generally, see Lightman, *Victorian* 39-94. For high Anglican natural theology, see Corsi; Topham, 'Science and Popular' 420-423, 'Science, Natural Theology, and the Practice'. For liberal Anglican, see Morrell and Thackray. For evangelical perspectives on natural theology, see Astore; Baxter; Bebbington; Fyfe, *Science*; Topham, 'Science, Natural Theology, and Evangelicalism', 'Science, Natural Theology, and the Practice', 'Science and Popular' 423-439. For Tractarian, see Morrell and Thackray; Prickett. For Unitarian, see Corsi 27; Topham, 'Science, Natural Theology, and the Practice'. For other groups see Cantor, *Quakers*. For the mutually-destructive effect of natural theologies growing out of different denominational traditions, see Brooke, 'Natural Theology and the Plurality'.

Consideration of natural theology's function and variety has merged in scholarship cognizant of the denominational cultures of early nineteenth-century Britain, establishing the sheer diversity of natural theologies across different religious sects.[29] Although natural theology and invocations of design played a 'mediating role' in establishing common ground between scientists of differing religious persuasions, according to Brooke, the status of natural theology as apologia, theology, and science was different in different denominations.[30] Broadly speaking, mainstream natural theology as a recognized apologia was an Anglican endeavour, valued for its broad religious appeal and, therefore, as a foundation for maintaining the social and political order.[31] With the advice of leading Anglican High-Churchmen, William Howley (Archbishop of Canterbury) and Charles James Blomfield (Bishop of London), the Bridgewater authors were selected partly for their 'complete theological orthodoxy', three of them being in Anglican holy orders (Whewell, Buckland, Kirby) and a fourth a Scottish Evangelical minister (Chalmers).[32] But liberal Anglican confidence in natural theology's broad appeal was upset by denominational disagreements. Generally, Evangelicals critiqued natural theology as theology because of their belief in the fallenness of human reason. Yet when its epistemological limits were recognized, natural theology—or theologies of nature—had a role to play in Evangelical versions of popular science, making it safe and giving it a devotional purpose.[33] Likewise, emphasizing Divine Revelation, High Church Anglicans employed design discourse for making science safe but questioned natural theology's apologetic efficacy and theological implications.[34] Those even higher, the Tractarians, were often sceptical about natural theology, seeing in it a theological laxity and latitudinarianism at odds with their ethos of tradition, duty, and dogma. And their belief that science had little to do with the most important questions meant they did not need design discourse as a frame for popular science.[35] This array of attitudes towards natural theology expands with the inclusion

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See Gascoigne on specifically Newtonian natural theology; Gillespie, 'Natural' on natural history and natural theology; Brooke and Cantor 314-346 and Brooke, 'Religious Apologetics' on chemico-theology; and Topham, 'Biology' on natural theology of the life sciences.

[29] This awareness of denominations was spurred by Brooke's 1979 warning that 'failure to relate contending schemes of natural theology to the respective religions traditions of which they can be an expression' leads to distortions in the historiography of natural theology ('Natural Theology of the Geologists' 41).

[30] Brooke, 'Natural Theology of the Geologists' 39, 46.

[31] On the power of design rhetoric to achieve these goals, see Morrell and Thackray 22-31.

[32] Brock 168, 174.

[33] On safe Evangelical science, see Topham, 'Science and Popular' 423-429. On Evangelical, devotional theologies of nature, see Astore; Fyfe, *Science*.

[34] On high church Anglican valuation of design for securing science, see Topham, 'Science and Popular' 420-423.

[35] On Tractarians and science, see Corsi 136-137.

Dissenting sects. Unitarians, still following Joseph Priestley, championed natural theology, but took it in the socially-dangerous deistic direction.[36] Valuing the 'Inner Light' over reason, Quakers were largely uninterested in natural theology as rational apologia but prized the experience of design.[37] Finally, Jews produced few natural theologies, for reasons internal to Judaism including an emphasis on Revelation and no felt need to demonstrate God's existence or character.[38]

The variety of denominational attitudes toward natural theology is even more complex than my above generalizations admit. In an essay surveying reviews of the Bridgewater Treatises published in denominational periodicals, Topham has demonstrated that perspectives on natural theology were not even consistent within one religious body.[39] Thomas Chalmers is a test case of this point, which Topham also explores. Although remaining an Evangelical, Chalmers changed his mind on natural theology, going from early resistance to becoming an 'exponent of a distinctively evangelical natural theology' (Topham, 'Science, Natural Theology, and Evangelicalism' 145). A single person's perspective on natural theology could also change as he shifted on the denominational spectrum. Initially critical of design from within a High Church tradition, Baden Powell gradually changed his mind, eventually championing a particularly liberal version of it.[40]

The varieties of denominational perspectives, the variation within denominations, and the shifting attitudes of Chalmers and Powell reflect the sheer diversity of nineteenth-century natural theology. Advancing the project initiated by Brooke, Topham has made this complexity his thesis and taken complexification as his methodology. He has traced the meanings individual readers created for natural theology and then the uses to which they put it, giving it as many varieties as there were readers, reviewers, distributors, and educators interpreting it.[41] Exhibiting a 'lack of a concerted plan' in organization and application (J. Robson 73), the Bridgewater Treatises have been the place across which many of these synchronic divergences and tensions have been traced, and so will anchor my own discussion.[42] Although largely Anglican, their cultural authority and importance were filtered

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[36] On Unitarians, see Topham, 'Science, Natural Theology, and the Practice' 49.
[37] Canter, *Quakers* 235-236.
[38] Cantor, *Quakers* 308-314.
[39] Topham, 'Science, Natural Theology, and the Practice' 46.
[40] Corsi traces this shift.
[41] Topham, 'Beyond', '"Infinite Variety"', 'Science and Popular'.
[42] For the Bridgewater Treatises as scholarly foci, see Brock; Cannon 8; Dillenberger 208-212; Gillespie, 'Preparing' 228; Gillispie 209-216; Topham, 'Beyond', 'Science and Popular', 'Science, Natural Theology, and the Practice', 'Science, Religion' 224; J. Robson; Yeo, 'Principle'.

through myriad denominational, political, class, gendered, regional, and personal perspectives.

The Bridgewater moment, from 1833 to 1837, is also a major marker for tracking natural theology's diachronic change. Some scholars take it as the end of Newtonian natural theology while others see it originating 'the positions which formed the background of the Darwinian debate'.[43] Still others get more personal, looking at the changing attitudes of specific natural theologians through time, with the Bridgewater Treatises a significant milestone.[44] Indeed, the natural theology of the 1830s differed from the natural theology that came before and after it, even though there are important continuities. The ubiquity of Paley's work through the century does not mean that the Bridgewater Treatises were mindless and anachronistic repetitions of it. Instead natural theology flexed and changed as its popularity waxed and waned. Despite frequent new editions of Paley's work, natural theology experienced a cultural slump in the 1810s and 20s for a number of reasons.[45] One was the lack of a pressing exigency. Socially, the Napoleonic Wars unified the country against a common enemy, hiding denominational differences and making design as common ground a redundant social glue. Scientifically, most disciplines had relatively untroubled relationships with religion, making natural theology superfluous in its capacity as a mediator. Religiously, perceived consensus on God's existence and the Bible made new natural theologies unnecessary, shifting religious discussion to more sophisticated theological questions.[46] Apologetics followed, defending Christianity specifically rather than God's existence.[47] Another reason for the slump was direct critique. Within physiology and medicine, Paley's work became 'a political lightning rod' as ambitious middle class doctors criticized it as representative of the socially-exclusive medical establishment.[48] It was even critiqued within the religious community, attacked for its 'weak epistemological status' by prominent High Church theology professors at Oxford, like William Van Mildert, Edward Copleston, and Richard Whateley (Corsi 68).[49] So although the constant republications of Paley established continuity in the natural theological tradition, the social, scientific, political,

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[43] Gascoigne; Ruse, 'Relationship' 505.
[44] On Chalmers's change of mind on natural theology, see Topham, 'Science, Natural Theology, and Evangelicalism'; on Powell's, see Corsi.
[45] Topham, 'Biology' 91-93.
[46] Corsi 64.
[47] John Bird Sumner's *The Evidence of Christianity, Derived from its Nature and Reception* (1824) offered 'moral evidence' of Christianity's legitimacy while Thomas Chalmers saw natural theology as superseded by the 'historical evidence of Christianity' (Topham, 'Science, Natural Theology, and Evangelicalism' 158) in his 'Christianity' entry for Brewster's *Edinburgh Encyclopaedia* (1813).
[48] Desmond, 'Artisan'; Desmond and Moore 219; Eddy and Knight xxv.
[49] Corsi; Topham, 'Science, Natural Theology, and Evangelicalism'.

and religious conditions of the first three decades of the nineteenth century also altered its shape.

New conditions in the 1830s then fostered a new natural theology. Along with widespread social, political, religious, and scientific discord, technical advances in printing and the growth of adult education and popular science made natural theology both available and useful in the 1830s, experiencing what Topham has called its 'indian summer'.[50] The possibility of political revolution struck fear into the hearts of the British middle and upper classes and hope into the hearts of radicals and working men. This political radicalism was associated with Dissent, deism, and atheism.[51] Science became a major battleground for the hearts and minds of Britons, as the wrong kind of science was perceived as leading to atheism, then radicalism, then revolution.[52] So for those desiring to maintain the status quo, to broadcast their own respectability, or to guarantee science's safety, natural theology became a useful tool. According to Brooke, the looseness of natural theological propositions allowed natural theology to 'serve a socially diplomatic purpose during a period when religious deviation had, or was certainly seen to have, social consequences'.[53] Functioning as 'common ground' between scientists of different denominations, invocations of design multiplied as scientists and popularisers sought to shelter their work within socially-safe theological orthodoxy.[54] Such invocations of natural theology protected scientists and science from alignment with Dissenting or radical threats to the social, political, and religious establishment and masked any religious aberrancy. Thus the Bridgewater Treatises provided 'safe science', as Topham labels it—safe for its religious, social, and political implications.[55] This was no longer Paley's natural theology, but something which responded to the exigencies of its time.

Natural theology continued to change in the subsequent decades. In the 1840s, the anonymous publication of Robert Chambers's evolutionary *Vestiges of the Natural History of Creation* (1844) put natural theology on the defensive, eliciting works like William Whewell's *Indications of the Creator* (1845) and Hugh Miller's *Footprints of the Creator* (1849), but also framing natural theological debate in terms of natural law and the question of

[50] 'Science, Natural Theology and the Practice' 37. Topham, 'Beyond', 'Science and Popular'.
[51] On this connection, see Marsh 60-77.
[52] Topham, 'Science and Popular'
[53] Brooke, 'Natural Theology of the Geologists' 39.
[54] Topham, 'Science and Popular'.
[55] Topham, 'Science and Popular' 404.

species.[56] In the 1850s, William Whewell's denial of extra-terrestrial life in *The Plurality of Worlds* (1854) induced a massive natural theological debate with David Brewster.[57] Finally, while the publication of Darwin's *On the Origin of Species* in 1859 is sometimes identified as natural theology's death-blow, it survived, even if under more difficult conditions.[58] Although fewer overt natural theologies were published, the 'narrative of natural theology' continued to structure popular science through the century.[59]

While scholars agree that natural theology was in constant flux in the nineteenth century, they disagree about how to interpret this variety, on whether it was destructive or helpful. It has been characterized contradictorily as fragmentation, ambiguity, resilience, mutual destruction, imprecision and emasculation, and elasticity and pliability.[60] Yet if its continued usefulness reveals natural theology's continued cultural relevance, its variety also indicates its continued vibrancy, its ability to adapt to and be altered by a changing cultural context. Indeed, natural theology is alive and well today, evidenced by the Intelligent Design movement in the United States, but also by the more intellectually-sophisticated annual Gifford Lectures hosted jointly by the Universities of Edinburgh, Glasgow, Aberdeen, and St. Andrews.[61]

Within this broad-brush account of change across the century, smaller and more nuanced changes were taking place in the natural theology of the 1830s. It was far from unified; several philosophical questions with multiple answers produced divergences and tensions within it. Should miracles be included in natural theology or excluded because they are *super*natural?[62] Should morphological theories be accepted?[63] How do the natural and

[56] For natural theology in response to the *Vestiges*, see Baxter; Brooke, 'Richard'; Ruse, 'Relationship'. On this re-framing, see Corsi 271; Secord xliv.
[57] On this debate, see Astore 75-85; Brooke, 'Natural Theology and the Plurality'; Ruse, 'Relationship'.
[58] On its survival, see Bowler, 'Darwinism'; Lightman, 'Visual'; J. Smith, 'Philip'.
[59] Lightman, *Victorian* 39-94. For natural theology in late-century popular science, see Lightman, 'Visual'; J. Smith, 'Philip'.
[60] As fragmentation, see Brooke, 'Natural Theology and the Plurality' 228. As ambiguity, see Brooke, 'Natural Theology of the Geologists' 43-44. As resilience, see Brooke, *Science* 193-195. As mutual destruction, see Brooke, 'Natural Theology and the Plurality' 264. As imprecision and emasculation, see Morrell and Thackray 227. As elasticity and pliability, see Gascoigne 220.
[61] Since 2000, Gifford lecturers have included Steven Pinker, Noam Chomsky, Bruno Latour, and Rowan Williams (forthcoming). Although Lord Gifford's will intended the lectures to 'promote and advance among all classes of the community the true knowledge of Him Who is, and there is none and nothing besides Him, in Whom we live and move and have our being, and in Whom all things consist, and of man's real relationship to Him Whom truly to know is life everlasting', he also stipulated that this natural theology be treated as a 'strictly natural science' and that the lecturers 'may be of any religion or way of thinking, or as is sometimes said, they may be of no religion, or they may be so-called sceptics or agnostics or freethinkers, provided only that the "patrons" [executors] will use diligence to secure that they be able, reverent men, true thinkers, sincere lovers of and earnest inquirers after truth' ('Lord').
[62] Cannon 6.
[63] Yeo, 'Principle'.

the scriptural revelations relate?[64] How are suffering and evil to be accounted for?[65] What is the best epistemological foundation for natural theology?[66] What is its religious function and apologetic efficacy?[67] But the key question was about evidence: what kind was the best? Why? At the simple level, this could be a debate about whether the solar system or the human body were better evidence.[68] Or it could have deep philosophical roots: were contrivances sourced in divine intervention or was the consistent action of the laws of nature the better evidence of design?[69] Commentators divide the answers into surprisingly similar categories: Ruse into final cause and uninterrupted laws; Brooke into 'miraculous contrivance' and the 'uniformity of nature'; and Corsi into divine interference and uniform laws.[70] Yet the duality they identify manifests differently according to which part of design is emphasized. In terms of the understanding of nature in nineteenth-century natural theology, the duality is between Paleyan contrivance and the laws of nature. But in terms of how God is understood, the duality is between God's miraculous intervention and God's wisdom to design a system that can run independently. Although both types existed right through the century, natural theology shifted from drawing primarily on miraculous contrivance to drawing on uniform natural laws between the 1830s and 1870s, as Corsi's *Science and Religion* has masterfully traced.[71]

While existing scholarship has painted a compelling portrait of 1830s natural theology, the picture is far from complete. One frame dominates: natural theology is usually studied, per Brooke, in relationship to science—for what it reveals about the relationship between science and religion in the nineteenth century—by scholars working within the history of science. So it is primarily studied as science and as the worldview of scientists, leading to neglect of natural theology as theology, let alone apologetics. Yet, as Timothy Larsen warns, the neglect of apologetics 'has left a regrettable gap in our understanding of religious and intellectual currents in the nineteenth century' (114). Science and its history

[64] J. Robson 97.
[65] J. Robson 93.
[66] Yeo, 'William' 495-498.
[67] Brooke, 'Indications'.
[68] Paley and Whewell favoured the body, while Brewster heartily defended astro-theology, see Brooke, 'Natural Theology and the Plurality'; Yeo, 'Principle' 277-281. Although largely concentrating on physico-theology, the Bridgewater Treatises also included new sciences like psychology, geology, and chemistry.
[69] Brooke and Cantor 179-180; Corsi.
[70] Ruse, 'Relationship' 509; Brooke, 'Natural Theology and the Plurality' 227; Corsi 236-242. Brooke also notices their multiplicity, rather than duality, in the context of teleological design arguments, including prospective contrivance adapted to the animal's surroundings and to its good, designed laws, divine archetypes, and like minds ('Between' 56-65).
[71] This narrative is generally accepted by Brooke; Brooke and Cantor; Ospovat, 'Perfect' 34-35; Ruse, 'Relationship'; Topham.

alone cannot give a full picture of historical natural theology. Looking at natural theology as theology, then, I hope to observe its interactions with other things than science. A simple historical fact provides my starting place: the simultaneity of natural theology's apotheosis with widespread fascination for technology.

I also depart from existing scholarly methodology on natural theology's multiplicity by taking it as a recognized categorical body of thought embodied in a genre. Diversity is both a historicist thesis about natural theology and an assumption underpinning the dominant methodology used to investigate it. Rejecting the sweeping generalizations and reductive oversimplifications of earlier intellectual historians and historians of science, Brooke substituted the case study leading to complexification, considering individuals in context. Although written from a variety of methodologies, including the sociology of knowledge, reception theory, book history, the history of education, intellectual history, and the history of rhetoric, subsequent scholarship has followed suit, making the case study and its micro-historical sensitivity central to the project. Informed by reception history and by historicist recovery of personal agency, this individual focus easily falsifies generalizations about 'natural theology', complicating my approach to it as a category. If I talk about 'natural theology', this orthodoxy would ask, 'well, which natural theology? And whose natural theology?'

Ironically, ideas from reception history and theory help me answer these questions, founding my approach to natural theology as a 'genre'. Reception theorist Hans-Robert Jauss suggests that a reader approaches a text with a 'horizon of expectations', that the genre a reader assigns a text before reading it determines his expectations of it. While each act of reading subtly adjusts the reader's 'horizon of expectations', genre remains an important dimension of reading, writing, and interpretation. As a genre then, a generalized 'natural theology' existed in the nineteenth century with shifting but bounded horizons of expectation. This, of course, does not mean that any individual instantiation fits specifically within those horizons, that it has all the characteristics of the genre.[72] But it does mean that any text exists in relationship to the 'genre', both being read through it and changing its shape. Genre then is not a list of shared qualities and topics, but a recognized category, a set of expectations with which a reader or writer approaches a text. While I heed Brooke's warning about

[72] Exchanging Jauss's geographical and optical metaphor for Wittgenstein's rope metaphor will help explain how specific instances of natural theology relate to natural theology as a genre. In exploring family resemblances in language, Wittgenstein noticed that no single strand runs through an entire length of rope, but the combination of strands plaited together formed a unified line. Similarly, a genre consists of multiple qualities, but no single text contains them all, just as no cross-section of rope will include each individual fibre, see Wittgenstein 33 (Section 67).

reductive generalizations, I also maintain that descriptions of natural theology as a genre are not meaningless reductions but describe communally-shared horizons of expectations. In the phraseology of another methodological tradition, natural theology was not just private conviction, but it was a recognized mode of public knowledge, a shared discourse through which people saw, discussed, and understood the natural world.

Topically and methodologically informed by but differing from existing scholarship, I also want to ask different questions. Where Brooke asked what work natural theology did, I want to ask to an engineer's question: *how* did it work? What made design as a way of thinking possible, plausible, and appealing within its specific historical context? Looking at natural theology as apologetics, I hope to understand how it was a persistently plausible way of thinking. It is not enough to say that natural theology persisted because it was useful. To do so opens natural theology to the charge of being mercenary, implying that its internal content did not have to be plausible as long as it was externally useful. An answer, I think, can be found in the conceptual metaphors which constituted natural theology and linked its content with its context. That natural theology thrived when fascination with technology burgeoned was not a fluke, but the foundation for the design analogy's—and therefore natural theology's—plausibility.

There is evidence for design's persistent plausibility beyond the popularity of the Bridgewater Treatises. Even Charles Darwin, the alleged murderer of design, admitted its cognitive appeal to a liberal defender of design, the Duke of Argyll, who recorded the scene:

> I said it was impossible to look at these [wonderful contrivances for certain purposes in nature] without seeing that they were the effect and the expression of Mind. I shall never forget Mr. Darwin's answer. He looked at me very hard and said, 'Well, that often comes over me with overwhelming force; but at other times,' he shook his head vaguely, adding 'it seems to go away'. (Argyll, 'What' 244)

Although faltering, the conviction of design remained an insistent and almost intuitional force in Darwin's mind—and in the larger British culture late into the century.

If the genre of natural theology indicated what people understood as a body of thought, Darwin's anecdote indicates the shape of that 'thought'. Scholars tend to prefer a concrete understanding of design as (ultimately-flawed) logic, specifically the teleological argument recognized by its search for beneficial purposes in nature.[73] But design was not only—nor primarily—a logical argument or sociological tool in early nineteenth-century Britain. Instead it was a cognitive category; it was common sense; it was the habitual shape of thought, the well-worn path of the mind on autopilot. It had the seductive potency of self-evident intuition rather than the coercive force of logical formulae. Only Colin Jager has explicitly studied design in this non-logical form. In *The Book of God: Secularization and Design in the Romantic Era* (2007), Jager presents design not as an intellectual activity or logical argument to be deployed, but rather as a system of practices, feelings, and beliefs into which the genre of natural theology fits. Calling it an 'argument from perception' (111), Jager suggests that 'its strength resides in the largely unarticulated predispositions, habits and attitudes that live below the threshold of reason' (11-12). But Jager was preceded in this understanding by some of the natural theologians of the 1830s, who understood design as a category of human thought and perception that merely needed to be awakened by appropriate evidence.[74] But where these pre-Victorians saw it as an inherent category of thought along Kantian lines, Argyll's Darwin anecdote indicates otherwise. Showing that design failed when offered within a different context, it suggests that design is not an inherent mental category, but a culturally-dependent one both constructed by its cultural context and dependent on that context for its plausibility. So the anecdote pushes us toward historicist orthodoxy: context matters. Scholars have recognized the dual context-dependence of natural theology. On the one hand, design changed and shifted as it responded to contextual changes, needs, and challenges. On the other hand, design could only succeed under certain historical conditions.[75] Here, then, is the historical seam which this project will mine: it will excavate the cultural construction plus the cultural conditions of design as a cognitive category embodied in and perceived through a genre.

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[73] Even many natural theologians see teleology as central to design: when dealing with the problem of an 'unmechanical looker-on' who does not understand how human designs work, Paley suggests that 'if we perceive an useful end, and means adapted to that end, we perceive enough for our conclusion' (43).

[74] In his Bridgwater Treatise, Whewell admits that the perception of design in nature does not produce a logically demonstrative proof of God, but non-rationally produces a perception of his existence and character (*Astronomy* 293-295). Thus the design analogy is a psychological process, one of the 'habits of thought' (146) rather than an apologetic tool to be applied to minds from the outside. David Brewster complained, in his *Edinburgh* review, that Whewell did not provide 'unimpeachable proofs of design in created things' (428). In reply, Whewell reasserted that his purpose was to invoke the perception of God, 'to call up this sentiment in the minds of others' ('Bridgewater' 265) rather than prove it demonstratively. Others, including Colin Maclaurin and Williams Irons, also recognized the intuitive power of design (Maclaurin 381; Irons 176-77). Jager and O'Flaherty even read Paley as cultivating the intuition or emotion, rather than logic of design (Jager 112; O'Flaherty, 'Part 1' 20). The view that design is a mental category is a strangely Kantian one, which makes sense for Whewell, whose affinities with Kant have been noted, see Yeo, 'William'.

[75] Brooke and Cantor 143; Gascoigne 219.

Methodologically, context matters in two ways for my study of design as a cognitive category in early nineteenth-century Britain. To structure my approach, I borrow one idea from the sociology of religion and one from reader-response theory, both methods setting aside a form's logic in accounting for its success. Sociologist of religion Peter Berger has famously postulated 'plausibility structures', defined as 'the particular social context in which a given belief or value is plausible' (*Far* 125), to explain why a belief is possible in one time or place while impossible in another.[76] Such plausibility structures explain why a certain way of thinking is a 'taken-for-granted truth' (125) at a certain time. For Berger, the relationship between social context and religious belief or value is also dual: social conditions both construct and serve as the plausibility structure of that belief or value.[77] I would like to borrow this concept of 'plausibility structures', but also to wilfully change it in order to account for design's continuing potency in the early nineteenth century. For Berger, as a sociologist, a 'plausibility structure' refers specifically to the *social* conditions which make a way of thinking possible. But I believe the concept could also be stretched to include the wider discursive and intellectual conditions of a cognitive category. The power of design as a 'taken-for-granted truth' depended on such a plausibility structure. And although such a structure is not monolithic but composed of a litter of assumptions and practices, I will focus in this project on what I think is the most important piece in this assembly: the multiple and changing meanings of machines and engineering that shaped and sustained the very concept of design.

My appeal to the meanings of machines brings me to my other theoretical informant: reader-response and reception theory. Stanley Fish explores the role of cultural context in reading, postulating 'interpretive communities' that largely share interpretations of a text because of their compulsory participation in a shared culture.[78] Adjusting this to figurative tropes, I believe that readers 'read' metaphors in the same way they read texts: from within an 'interpretive community'. Readers come to the design analogy at the core of natural theology from within an 'interpretive community' sharing understandings of human design and of human-made machines. Ultimately, I believe Fish's concept can be combined with Berger's concept: what design's 'interpretive community' knew forms part of its 'plausibility structure'. Mutually rebelling against the tyranny of logical content in *a priori* historical

[76] See also Berger, *Sacred* 45-51.
[77] Although not explicitly stated, Jager was working out the 'plausibility structures' of design in the Romantic era, working out how it was legitimated as a worldview. For Jager, natural theology functioned by reiterating old feelings so that they become 'embedded more firmly within the mental and bodily lives of persons' (11).
[78] Fish; Jauss.

accounting, Berger and Fish provide a methodological foundation on which to ask what the cognitive category of design looked like, what activated it, and what made it plausible in the early nineteenth century. Recognizing the continued functioning of a category of design within the mind, we must also consider the structure and shape of this category of mind—including the things which fulfil its parameters, turning like a key in the mental category lock. Basically, what did the 'interpretive community' know, think, or believe that served as the 'plausibility structure' for design?

Design as Metaphor: Conceptual Metaphor Theory

Constituting natural theology, 'design' has a specific formal structure: it is a 'conceptual metaphor' conditioning how natural theology is thought. It implicitly draws on shared knowledge about machines and engineering to make nature appear designed and to indicate the necessity for a divine designer. The design analogy thus binds natural theology to its technological context. Others have noticed the importance of *faber* metaphors to natural theology's fortunes. Linking technology and theology through metaphor, traditionalist historians identifying natural theology's decline with mechanistic science's end understood mechanical metaphors as structuring seventeenth- and eighteenth-century natural theology.[79] But what of the nineteenth century they ignored? While a few have studied the tropes present in natural theology's rhetoric, they have neither engaged with the theory of metaphor nor attended significantly to mechanical metaphors.[80] Thus nineteenth-century natural theology and its link to technology must now be reassessed in light of major developments in the theory of metaphor over the last three decades. My project returns to mechanical metaphors in design arguments through thorough engagement with recent theory of metaphor, also hoping to subtly contribute to that theory.

The study of metaphor shifted significantly over the twentieth century, from being primarily within literary studies to being a fully multidisciplinary field dominated by cognitive linguistics.[81] Taking metaphors as the special province of great authors, early century critics studied metaphors as decorative flourishes consciously deployed. Then, with

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[79] This approach may have been rooted in Stephen Pepper's *World Hypotheses: A Study in Evidence* (1942) which identified mechanism as a root metaphor structuring one of four dominant worldviews.
[80] On natural theology's rhetoric, see Brooke and Cantor 23-33; Gillespie, 'Divine'; J. Robson. On Paley's rhetoric, see Eddy, 'Rhetoric'; O'Flaherty, 'Part 1', 'Part 2'.
[81] For a brief history of metaphor theory, see Fludernik, Freeman, and Freeman, 'Metaphor' 384-387. Its multidisciplinarity is evident in the major collections of essays on metaphor: the special issue of *Critical Inquiry* entitled *Metaphor: The Conceptual Leap* (1978); Ortony (1979); Ortony (1993); Gibbs (2008).

the linguistic turn, metaphors were seen as participating in language's structuring of thought, explored in Paul Ricoeur's *The Rule of Metaphor* (1978). But within a few years, George Lakoff and Mark Johnson had published their ground-breaking *Metaphors We Live By* (1980), establishing the now dominant cognitive or conceptual metaphor theory (CMT).[82] They argued that all thought, knowledge, and action are structured by metaphors founded in physical and cultural experience. Metaphors are not decorations, but constitute human thought itself.[83] Not necessarily linguistic, they are the 'process of thought' rather than the mere 'product of language'.[84] This theory makes it possible to account for the continuing power of figurative tropes, like the design analogy, which are sometimes absent from explicit language, a project formalist approaches limiting metaphor to linguistic occurrences cannot conceive.

Importing cognitive metaphor theory into literary studies, I would also like to expand its horizons.[85] Although including culture as a factor in the formation of conceptual metaphors, Lakoff and Johnson gave universal physical experience the larger role in this formation.[86] But culture's importance has recently become a significant new direction in metaphor theory, led by Zoltán Kövecses in *Metaphor in Culture: Universality and Variation* (2005). Where Kövecses considers culture and metaphor atemporally, however, I would like to join a few others in studying metaphor historically, taking up a 1960 proposal of Hans Blumenberg, only recently made available in English, for a 'metaphorology'—a history of the 'absolute metaphors' behind philosophical concepts. In offering such a metaphorology of the design analogy and its parent trope, the mechanical metaphor, I hope to also contribute to theory about metaphor in cultural context and to specific historical thinking about metaphors in nineteenth-century British culture, a project that has barely been begun.

Where linguists define and demarcate metaphor carefully, cognitive metaphor theorists have been less interested in specificity. Lakoff and Johnson define metaphor simply as '*understanding and experiencing one kind of thing in terms of another*' (5). 'Fundamentally conceptual' rather than linguistic (272), this largely unconscious process

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[82] For a general introduction to metaphor from a CMT perspective, see Kövecses, *Practical*.
[83] Lakoff and Johnson turned metaphor theory toward conceptual rather than linguistic phenomenon, but they were not as original as they thought (Semino 9-10). In 1942, Stephen Pepper had postulated 'root metaphors' that founded all worldviews, while in 1960, Hans Blumenberg had postulated 'absolute metaphors', untranslatable metaphors at the core of thought.
[84] Fludernik, Freeman, and Freeman, 'Metaphor' 388.
[85] Essays in Fludernik's recent collection (2011) address some of the challenges of importing cognitive metaphor theory back into literary studies.
[86] Their 'Afterword' to the 2nd edition of *Metaphors We Live By* in 2003 expands the theory in light of a quarter-century of research, but hones in primarily on the physical and neurological, excluding the cultural.

involves the 'mapping' or 'projection' of qualities from the 'base' or 'source domain' to a 'target domain'.[87] Mappings are usually directional, with the more abstract structured by the more concrete.[88] They can involve any range of qualities, from object attributes or features to relational structures, at any level of specificity.[89] Within this theory, analogy becomes a species of metaphor that specifically maps relational structures from source to target.[90] Indeed, along with the retreat from mincing definitions, recent metaphor theorists have been uninterested in categorizing tropes.[91] Instead metaphor and its erstwhile opposites like metonymy or simile are placed in a 'continuum, not a dichotomy'.[92]

Since analogies are types of metaphors, recent metaphor theory provides an excellent foundation for understanding how the design analogy worked. Invoking perceived design in the natural world, the argument from design reasons by analogy with human designed arts that there must be a being who designed the natural world. As an analogy, design rests on the similarity between humanity's relationship with what it makes and God's relationship with nature. It is represented symbolically like this:

natural world : God :: artefact : maker.[93]

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[87] On its unconsciousness, see Kövecses, *Practical* 9. For the technical language, see Bowdle and Gentner 193; Gentner and Bowdle 111; Gentner, 'Structure' 157. Both 'mapping' and 'projection' are themselves metaphorical representations of the relationship between source and target. Many others have been offered. Black suggests that in metaphors we 'see' the target through the source or that we 'project' the source onto the target ('Metaphor' 288). Ricoeur lists a number of metaphors for metaphor, including filter, screen, lens, and mask (*Rule* 252). On the move from instrumental to processual metaphors for metaphors (i.e. from vehicle, tenor, ground, to source domain, target domain, mapping), see Fludernik, Freeman, and Freeman, 'Metaphor' 586-387.

The 'mapping' metaphor has been given empirical credence by research within the 'Structure Mapping Theory' of the way metaphors are processed by the mind, see Bowdle and Gentner 193, 197-198, 212; Gentner and Bowdle 109; Genter, Bowdle, and Wolff 202, 206-207, 209-210, 237-238.

[88] Kövecses, *Practical* 7. Established by Lakoff and Johnson, this directionality is usually from the physical to the nonphysical (59).

[89] Eubanks 426; Gentner, 'Structure' 157; Gentner and Kurtz 610.

[90] On analogy, see Gentner, 'Are' 108, 'Structure' 156; Gentner and Bowdle 109; Gentner and Jeziorski 448-449; Gentner and Kurtz 610. On metaphor, see Gentner, 'Structure' 161-162; Gentner and Bowdle 110-111. The more extended a metaphor is, the more likely it is to be an analogy (Gentner, Bowdle, and Wolff 201).

[91] This is in reaction to traditional metaphor theory grounded in Book 3 of Aristotle's *Rhetoric,* where he does just that: categorizes tropes.

[92] Gentner, 'Structure' 161; Gentner and Kurtz 636. On the blurring of metaphor and analogy, see Bowdle and Gentner 196-197, 208; Gentner and Jeziorski 452. On the variety of relationships between metaphor and analogy, in which sometimes analogies are metaphors and sometimes metaphors are analogies, see Ricoeur, *Rule* 23, 286, 257-313. On the dissolution of the distinction between metaphor and other tropes and on the importance of this dissolution in theoretical discussion, see Fludernik, Freeman, and Freeman, 'Metaphor' 384-386. For continued insistence on the distinction between metaphor and metonymy, see Lakoff and Johnson 35-40; and for metaphor and simile, see Glucksberg.

[93] In argument, it takes this form. But when natural theology is more corroborative, the analogy takes a different form:

God : natural world :: engineer : machine

This tends to assume both makers, focusing the import of the analogy on the maker's relationship to his product.

Linguistically represented, the natural world is designed and made by God in the same way that artefacts are designed and made by human makers. When used rhetorically, the design analogy algebraically uses the obvious existence of human makers, designed artefacts, and design in nature to argue for God. Although analogy was a valuable tool in nineteenth-century logic, I believe that design's appeal was not in its logical strength, but in its status as a 'taken-for-granted-truth' (Berger, *Far* 125), as a common sense view that was difficult to dislodge.[94] Far deeper than a surface rhetorical metaphor, the design analogy is one of Lakoff and Johnson's 'conceptual metaphors' that constituted the processes of thought.[95] It was not the novel metaphor of Romantic genius, but a conventional workhorse in early nineteenth-century religious thinking. The very popularity of natural theology as a genre points to the very cultural prevalence of design as a conceptual metaphor.

One source of design's power is its coherence with and corroboration by deeper, simpler metaphors. As with most complex metaphors, the design analogy rests on the combination of two more primary metaphors and draws on their conceptual resources: one understanding God anthropomorphically as a human and another understanding the natural world as a human artefact.[96] Religious anthropomorphism is nearly universal, with its variations produced by slight variations in understandings of the human. But the second is highly-culturally contingent, taking on the specific shapes that human-made things have taken over time. From the seventeenth century onwards, this shape was often mechanical. Mechanical metaphors present or describe something non-mechanical, like a body, mind, or function in terms of a machine's properties, functions, structures, or processes.[97] They are extremely flexible in how and what they describe: they are based on *relations* or *attributes* or both; they are *expressive* or *explanatory* or both; they project *rich*, but inconsistent, elements from the base or they project *systematic* networks of relations; they are *general* or *specific*, *abstract* or *concrete*. Their nineteenth-century scope was gigantic: machines could be used to

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[94] On the nineteenth-century value of analogy, see Eddy, 'Nineteenth' 101. On metaphors becoming common sense, see Semino 33.

[95] Alternatively, it is what Friedrich calls a 'title metaphor' or metaphor 'framing and inducing coherent worldviews' (285) or what Pepper calls a 'root-metaphor' at the source of worldviews (84-114).

[96] On the dependence of complex on primary metaphors, see Kövecses, *Practical* 84. Lakoff and Johnson also argue that successful metaphors are coherent with other metaphors (17-19).

Although he does not address the design analogy directly, Ricoeur comments obliquely on the three metaphors I have identified here: 'It is creative causality, therefore, that establishes between beings and God the bond of participation that makes the relation by analogy possible' (*Rule* 276).

[97] On mechanical metaphors, see Eubanks 430; Kövecses, *Culture* 111-113, *Practical* 17-18, 131-133; Lakoff and Johnson 27-28. For mechanism as a 'root metaphor', see Pepper 186-231; as an 'absolute metaphor', see Blumenberg 62-76.

describe society, the economy, the mind, nature, women, or literary form.[98] With a large family of machine and engineering tropes, then, 'mechanical metaphors' are parents to the design analogy. I study mechanical metaphors as conceptual metaphors underlying the design analogy, structuring the intellectual pathways of nineteenth-century consumers of natural theology and employing the culturally-constructed meanings of technology.

While mechanical metaphors were parent metaphors producing the design analogy as a conceptual metaphor, they were also servant metaphors which supported it. As scholars studying its discursivity have noticed, science incorporates metaphors in at least two ways: they are conceptual or root metaphors out of which theories grow and they are often part of the language in which science is discussed.[99] Part theology and part science, nineteenth-century natural theology fulfils this observation. While the design analogy was a species of conceptual mechanical metaphor, linguistic mechanical metaphors played an important role in design's explanations of the natural world. As a conceptual metaphor, the design analogy was given force by the explanatory power of linguistic mechanical metaphors, which ensured the perception of design in nature by treating it as an artefact. As Ricoeur puts it 'metaphor is the rhetorical process by which discourse unleashes the power that certain fictions have to redescribe reality' (*Rule* 7). If the design analogy is one of the 'fictions' redescribing reality, then linguistic mechanical metaphors 'unleash' its power.

Linguistic mechanical metaphors have another relationship to design: they indicate its continued functionality. Although mutually ignoring each other, theorists of science and of metaphor both prefer to study conceptual rather than linguistic metaphors. Yet the empirical methodology of conceptual metaphor theorists reveals the importance of linguistic metaphors: they offer the best access to the cognitive metaphors functioning within the mind, for metaphorical language can 'make conceptual metaphors manifest' (Kövecses, *Culture* 8).[100] Thus linguistic mechanical metaphors can indicate the presence of the design analogy coursing often visibly below the surface of natural theology as genre. For science, Bono points out that while linguistic metaphors in science are sometimes consciously chosen and manipulated for rhetorical effect, they are most frequently the spontaneous outgrowth of a

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[98] The 'scope' of a metaphor refers to the 'range of target concepts to which a given source domain applies' (Kövecses, *Practical* 118). On mechanical metaphors in poetics, see J. Hall; for novelistic form, see Otto; for society and the mind, see Ketabgian; for the normal mind, see Banfield; for the diseased mind, see Connor; for society and the economy, see Berg, *Machinery*; for women, see Inglis; on nature through the frame of physics, see Morus, *When*.

[99] On metaphor in science, see Barnes 49-57; Bono; Boyd; T. Brown; Gentner and Jeziorski; Hesse; Kuhn. Bono surveys approaches to metaphor in science (60-72).

[100] See also Lakoff and Johnson 7.

deeper metaphor structuring scientific thought. This warning must be heeded within the study of natural theology. Without this corrective, what Topham has called the 'discourse of design' peppering the writings of early nineteenth-century science could easily be interpreted as deliberate posturing by scientists to meet their own needs by making their work more palatable.[101] Instead, if we set aside what Ricoeur has called the 'school of suspicion' and take up what Sharon Marcus calls 'just reading' (75), then linguistic design discourse could indicate the continued functioning of design as a conceptual metaphor. Yet linguistic metaphors are not necessary for the continued functioning of design, even though they are bound tightly together. The close relationship between them has precipitated a significant error in the only scholar to have considered it. Gillespie, assuming their inseparability, notices that linguistic mechanical metaphors reinforced the design analogy for William Paley, but that they seemed to fade with the next generation of natural theologians. He concludes that their absence implies a separation of natural theology from its industrial context.[102] Instead, perhaps mechanical metaphors continued to structure natural theology, but from deeper down.

This tripartite layering of mechanical and design metaphors, in which mechanical metaphors both spawn and serve the design analogy, is complicated by the different rhetorical functions metaphors and analogies serve. At the structural level, analogies may be metaphors, but at the rhetorical level they are distinguishable. Analogies are often utilized for 'explanatory-predictive' purposes where metaphors fulfill both 'expressive-affective' and 'explanatory-predictive' functions.[103] Thus metaphors have at least three functions in natural theology. Most fundamentally, the design analogy structures natural theology as its central conceptual metaphor, itself dependent on an even more basic mechanical metaphor. Then natural theology as a logical apologia deploys the design analogy as a predictive, logical device. Finally, mechanical metaphors work within natural theology as explanatory tools which also carry expressive and affective potential.[104] As Nünning reminds us: 'there is always more semantic energy in a metaphor' as its meanings are 'numerous, complex, and contradictory' (256). Indeed, this potential constantly becomes actual: mechanical

[101] Both Robert Chambers in the *Vestiges of the Natural History of Creation* (1844) and Charles Darwin in *On the Origin of Species* (1859) are open to this charge.
[102] Gillespie, 'Divine'.
[103] Gentner, Bowdle, and Wolff 240. Boyd distinguishes between metaphors 'constitutive' of scientific thought and 'exegetical or pedagogical metaphors' (359-360). Indeed, metaphors can serve a variety of conceptual (Kövecses, *Practical* 32-36) and linguistic functions (Cameron 203-207).
[104] On the context-dependent potentiality rather than just actuality of a metaphor's meaning, see Biebuyck and Martens 63.

metaphors, whether the design analogy itself or the explanatory linguistic metaphors it employs, always involve the logical and expressive functions simultaneously.[105] Intended or not, the predictive always carries the affective. Indeed, the predictive would have very little power without the affective appeal and implications of a metaphor.[106]

The work metaphors do raises the question of how metaphors work. Aristotle famously claimed in the *Poetics* that metaphor involves the perception of similarity in dissimilars, while, more recently, Kövecses has noticed that only some qualities of the source are mapped onto the target, an asymmetry he calls 'partial metaphorical utilization'.[107] So for any single metaphor, which qualities are mapped from the source to the target? And how are they determined? A number of theories try to account for this 'motivation' of metaphorical mappings.[108] Max Black's early, speculative 'interaction theory' suggested that the two domains interact to determine which qualities will be selected.[109] More recent empirical structure-mapping theory argues that in processing a new metaphor the mind first compares each domain (alignment) and then selects the 'structurally consistent' match which will form the core of the metaphor. After alignment, other elements from the source are projected onto the target if they are coherent with the foundational match.[110] This metaphorical 'entailment', defined as the mapping of rich knowledge about the source onto the target 'beyond the basic correspondences' between them, then has the power to structure entire discourses.[111] However, novel and conventional metaphors are processed differently. For conventional metaphors, the mind automatically selects conventionalized qualities without bothering with alignment.[112] There are a number of other theories of motivation as well: mappings are determined by contextual 'licensing stories', by linguistic convention, and by

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[105] Bono observes that scientific metaphors carry 'cognitive content' plus 'emotive and affective associations' (68).
[106] On the importance of feeling in the creation and interpretation of metaphors, see Ricoeur, 'Metaphorical' 155-159.
[107] Kövecses, *Practical* 79-92. In reverse, Lakoff and Johnson suggest that projection from the source highlights and hides some qualities of the target (10-13).
[108] Mappings can be 'motivated' by perceptual, biological, and cultural experience, see Kövecses, *Practical* 67-77. On 'Models of Metaphor Processing', see Giora 144-147.
[109] Black, 'More' 29.
[110] On projection, see Bowdle and Gentner 196-197; Gentner and Bowdle 112. On systematicity, see Gentner and Bowdle 110; Gentner, 'Structure' 162-163. Kövecses calls the rule governing this second step the 'invariance principle' which requires the mapping of as much knowledge about the source as is consistent (*Practical* 103).
[111] On defining entailment, see Kövecses, *Culture* 7. For an introduction to metaphorical entailment, see Kövecses, *Practical* 93-105. On the structure of discourses, see Kövecses, *Practical* 95. For the importance of entailment for the 'root metaphors' of worldviews, see Pepper 91.
[112] Gentner and Bowdle 116.

physical neural pathways.[113] Even the directional idea of 'mapping' or 'projection' has been abandoned by some to talk about 'blending' in which source and target both project qualities into a third, mixed domain.[114]

Yet none of these theories can explain every instance of a metaphor, for the function a metaphor plays can determine which qualities are mapped: expressive metaphors favor richness by projecting as many qualities as possible without regard for consistency, while explanatory metaphors require consistency.[115] While I find structure-mapping theory the most compelling, I return methodologically to Black's simplest statement on mappings: metaphors draw on a '*system of associated commonplaces*', using those most readily available ('Metaphor' 287). Kövecses echoes this point: metaphorical entailment is based on the '*folk understanding*' (*Practical* 104) of the source domain, as its 'main meaning focus' is culturally-predetermined and culturally-shared (*Culture* 11-12).[116] A metaphor will map what makes sense based on what is most prominent in the meanings of the source and of the target. Of course, what is 'commonplace' or a 'folk understanding' is culturally-determined and so is multiple and constantly changing. Thus metaphors become a 'medium of exchange', connecting one ever-changing discourse to another equally open discourse (Bono 61, 72). For mechanical metaphors, including the design analogy, in historical context, this means that the qualities projected were always changing, sensitive to the shifting 'system of associated commonplaces' and 'folk understanding' of machines and engineers. The problem then was how much was projected and which mappings were appropriate.

This cultural-dependence of metaphors was vaguely acknowledged by theory, yet largely ignored in practice until very recently, where it has become a major melody in metaphor studies.[117] In an early and influential statement from outside cognitive metaphor theory, Philip Eubanks suggested in 1999 that 'because metaphors are always uttered by historically and culturally situated speakers, metaphoric mappings are subordinate to the speakers' political, philosophical, social, and individual commitments' (419). Ansgar Nünning migrated this insight into a cognitive metaphor framework in 2002, picking up

[113] On licensing stories, see Eubanks. On linguistic convention, see Kövecses, *Practical* 9. On neural theories, see Lakoff; Lakoff and Johnson 252-254.

[114] For introductions to conceptual integration theory and blending theory, see Fauconnier and Turner, 'Conceptual'; Turner and Fauconnier.

[115] Gentner, 'Are' 128. On the variety of ways metaphors are processed by the mind, see Kintsch.

[116] On the 'main meaning focus' of a metaphor, see Kövecses, *Practical* 107-120.

[117] For vague acknowledgments of culture, see Lakoff and Johnson 19; Turner and Fauconnier 409. G. Olson critiques cognitive metaphor theory for ignoring the cultural-embeddedness of all physical experience. For a defence of culture in CMT, see Yu.

This tune was whistled much earlier by those studying metaphors within science studies (Bono 57) or within studies of rhetoric (Booth, 'Metaphor' 60).

inherent strains in that theory. In 2005, Kövecses's *Metaphor in Culture* showed how cognitive metaphor theory can account not only for the universality of many conceptual metaphors, but also for their variation within and across cultures. Basically, he argues that all conceptual metaphors have a universal core based on universal experience, but that they take on specific cultural shapes. Since then two collections of essays have expanded this project of considering the relationship between metaphor and culture.[118] My project seeks to answer their call for more work in this area by studying a specific metaphor and historicizing it within its cultural context. In some ways, this reading is similar to undergraduate close readings. It notices a metaphor and asks what the source of that metaphor means in order to discover qualities which are projected onto the target. But it also differs. Borrowing from cognitive metaphor theory, it seeks metaphors not in language but in the very structure of thought. It recognizes, with Eubanks, the 'cultural motivation of metaphor mappings' (421) with an acknowledgement of the openness of those mappings.[119] It asks which qualities were projected in the design analogy and in mechanical metaphors, why, where they came from, and how they changed.

The question of how mechanical metaphors changed can only be dealt with after acknowledging *that* they change. Implicit denial of design and mechanical metaphors' openness to change has led to the historical error about design's demise around 1800. Instead, I argue that metaphors are not static, but metamorphose, devolve, shift, disappear, reappear, are created, and ossify into conventional language. As Beer puts it, 'metaphor is never fully stable. It initiates new meaning but not permanent meaning' (*Darwin's* 85). One way—among many—they can change is through the changing meanings of the source domain on which a metaphor draws.[120] As Bono has noticed 'metaphors and tropes may be transmitted over time' but 'their meaning must always be reconstituted synchronically. That is to say, such meanings are socially and culturally situated, carrying resonances that speak forcefully to individual members or specific communities' (77). This warning must be

[118] Most recently, *The Cambridge Handbook of Metaphor and Thought* (2008) edited by Raymond Gibbs collectively registers the '"paradox of metaphor," in which metaphor is creative, novel, culturally sensitive, and allows us to transcend the mundane while also being rooted in pervasive patterns of bodily experience common to all people' (Gibbs, 'Metaphor' 5). The 2009 edition of *REAL: Yearbook of Research in English and American Literature*, edited by Herbert Grabes, Ansgar Nünning, and Sybille Baumbach, and titled *Metaphors Shaping Culture and Theory*, brings together cognitive metaphor theory, literary studies, and cultural history, the editors arguing that 'such an alliance could open up productive new possibilities for the analysis of both the relationship between metaphors and their cultural contexts, and the cultural implications and functions of metaphors' (Nünning, Grabes, and Baumbach xx).
[119] Some deny that mappings can be predicted, see Eubanks 420-421; Kövecses, *Practical* 68.
[120] On metaphors changing, see Eubanks 438. Kövecses demonstrates that all the components of a metaphor can vary (*Culture* 117-130).

carefully heeded with mechanical and design metaphors because so many generalizations about what they are and how they work have abstracted them from the historical contexts in which they made sense to a specific 'interpretive community'. For me, paying attention to their cultural context means attending to the source domains on which they drew (machines and engineering), what their meanings were, and how they were constructed. Generative and transformative, natural theology's metaphors linked it to seemingly unrelated discourses, specifically to the textual construction of the meanings of machines.[121]

Although inherited, design and mechanical metaphors are characterized by what Bono calls the inherent 'unruliness of metaphor' (66) and what Ricoeur calls their 'semantic dynamism' (*Rule* 298). This 'unruliness' and 'dynamism' constantly disrupt the mechanical metaphor's perpetual slide toward conventionalization, a state in which the metaphor would draw on a pre-established 'metaphoric category' rather than on the localized meanings of machines.[122] Although it had a long history and has been treated as an ossified conventional metaphor, the mechanical metaphor was never fully conventionalized as that process was constantly delayed by a changing cultural milieu—by the changing meanings of machines in a time of dynamic technological and cultural change. The always incomplete conventionalization kept the metaphor open to the changing features of what humans made and how. Emphasizing these synchronic conditions, this project offers a historical metaphorology for a specific metaphor, the design analogy and its corroborating mechanical metaphors, at a specific moment. Joining a few other accounts of specific nineteenth-century metaphors, it seeks to found that history more thoroughly on the theory of metaphor.[123]

This project explores a complex of interrelated questions which arise from applying this summary of metaphor theory to design and mechanical metaphors. First, the rest of this chapter will investigate the design analogy's specifically mechanical form and trace how it took on that form historically, reading linguistic mechanical metaphors in the Bridgewater Treatises as evidence of the continued mechanical form of the design analogy in the 1830s. Then the next four chapters will explore which meanings of machines were utilized in 1830s design arguments and what work those meanings did. Chapter two will look at the construction and utilization of machines as comprehensible objects in natural theology. The next three chapters will look at more complex relationships between technological discourses

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[121] On tropes connecting scientific discourse to other discourses in a generative and transformative way, see Bono.
[122] On conventionalization, see Gentner and Bowdle.
[123] Beer looks at natural selection as a metaphor, supported by the metaphor theory of her time (*Darwin's*); Ketabgian looks at machine metaphors for the mind and for society; Nünning explores the various metaphors used for empire; R. Young considers metaphors for nature.

and natural theology through metaphor. Chapter three will be about the aptness of the design analogy and how constructions of machines supported it. Chapter four will discuss how mechanical metaphors both raised and solved theological problems. And finally, chapter five will look at the systematicity of mechanical metaphors which dragged down the design analogy.

The Mechanical Clothing of Design though History

So far, I have discussed the connections that exist between mechanical metaphors and the design analogy *theoretically*. But they were also linked *historically*. This combination was historically contingent, forged only under certain conditions. While natural theology could take other forms than the design analogy, the design analogy could also do without mechanical metaphors by referring to artistic beauty, language, or law-giving instead of mechanical structure.[124] Rooted in the shared human experience of manipulating the physical environment, the design analogy assumed various shapes through time, influenced by the changing techniques of manipulating that environment.[125] But by the early nineteenth century, the design analogy had donned a thoroughly industrial and mechanical garb. Mechanical metaphors had become the culturally-variable cloak wrapping design as a universal conceptual metaphor.[126] Independent conceptual metaphors, industrial mechanical metaphors blended with the design analogy, ultimately coming to serve as its plausibility structure. A 'metaphorical conceptual system', this combination requires a 'cultural history' that explains how the two metaphors blended together through what Fauconnier and Turner call 'cobbling and sculpting' in the honing of any conceptual network ('Rethinking' 65, 53). Correcting faulty understandings of natural theology as diachronically homogenous and historically synonymous with the clock analogy, this section will trace the entry of the design analogy into natural theology and then how mechanical metaphors became intertwined with it. Establishing the historical separability of design and mechanical metaphors, this section will serve as a historical background for 1830s natural theology.

Like much of Western intellectual history, this story begins with the classics. Ancient Greek natural theologies employed a species of design argument: Plato's *Timaeus* posited a

[124] On other forms of natural theology, see the essays in Craig and Moreland.
[125] Although discussion is beyond the scope of this chapter, mechanical metaphors in natural theology are probably descendants of the metaphor-making experience of physical manipulation.
[126] The ubiquity of design as a conceptual metaphor is supported by how saturated biology is with the language of design, see Ayala; Beer, *Darwin's*; Nissen; Reiss.

'demiurge' and Aristotle's *Metaphysics* a 'prime mover' directing the cosmos.[127] Yet they reasoned *a priori* from evident design and *telos* without elaborating or even mentioning the design *analogy*. Archimedes's construction of an astronomical clock facilitated the introduction of the design analogy into natural theology. Cicero wrote about this clock in *De Natura Deorum*: 'When you see a sundial or a water-clock, you see that it tells the time by design and not by chance. How then can you imagine that the universe as a whole is devoid of purpose and intelligence, when it embraces everything, including these artefacts themselves and their artificers?' (159). By the third or fourth century, Lactantius had transferred this non-mechanical astronomical clock analogy into Christian apologetics.[128] From there, Christian thinkers continued to elaborate design. In his mid-thirteenth century *Summa Theologica*, Thomas Aquinas included the teleological argument for God as one of his Five Ways of knowing God's existence. Still non-mechanical though, Aquinas's design analogy depended on the final cause of an arrow's movement to carry its case.[129]

The design analogy did not don its mechanical garb until the 'Scientific Revolution' of the seventeenth century. Until then, proofs of God's existence had so relied on Aristotelian organic metaphors, in which the cosmos and its constituents were animated by living forces directed toward final causes, that alternative metaphors seemed to threaten received natural theology.[130] A major change came in the mid-seventeenth century: Robert Boyle attacked the Aristotelian conception of nature because it gave agency to nature instead of to God.[131] He then provided natural theology with a new foundational metaphor: the cosmos 'is like a rare clock, such as may be that at Strasbourg, where all things are so skilfully contrived that the engine being once set a-moving, all things proceed according to the artificer's first design' (*Free* 13).[132] This was not a one-off metaphor for Boyle, but one which he elaborated, extended, and nuanced as he sought to describe the 'right reason' which

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[127] On natural theology's classical origins, see S. Clark; Nadaff. The Bible includes many ancient Hebrew statements that are theologies of nature, rather than natural theology, see Rowland. Such statements can be found in the Psalms: 'The heavens declare the glory of God; and the firmament sheweth his handywork. Day unto day uttereth speech, and night unto night sheweth knowledge. There is no speech nor language, where their voice is not heard' (*KJV*, Ps. 19.1-3).
[128] Haber 10. On Christian interactions with Greek natural theology, see Pelikan. On Patristic natural theology, see Hankey.
[129] I, q. 2, a. 3.
[130] Brooke, *Science* 119; Ruse, 'Robert'.
[131] Boyle, *Free* 62.
[132] On Boyle's suggestion of this metaphor, see Ruse, 'Robert'. Boyle justified the selection of 'comparisons drawn from telescopes, microscopes etc' by saying that 'some experience has taught me, that such a way of proposing and elucidating things, is either more clear, or, upon account of its novelty, wont to be more acceptable, than any other to our modem virtuosi' ('Christian' 284; qtd. in Mulligan).

would give science a foundation and defend Christianity.[133] Although not the first mechanical clock metaphor, Boyle's use of it reflected the new science while also consolidating the design argument in England.[134] His natural theology ultimately edged out alternative versions because it was so deeply enmeshed with the concurrent Newtonian 'Scientific Revolution' and its mechanistic science.[135] The 'increasing use of mechanical metaphors to construe natural processes and phenomena' in Newtonianism 'fortified' and 'ratified' natural theology based on clockwork design.[136] In turn, mechanical natural theology also legitimated mechanical science.[137] Indeed, the natural theology and science of the seventeenth and eighteenth centuries were entirely entangled, and cannot be divided as twenty-first-century divisions of knowledge try to do.[138] For example, assuming that God was active in nature, Newton's reduction of the universe's working to a rational, simple, and quantitative order increased the strength of natural theology.[139] And in the first Boyle lecture (1692), Samuel Bentley began the adaptation of Newton's ideas to natural theology with Newton's blessing. From there a stream of Newtonian natural theology flowed, through both astronomy (Derham, Clarke, Maclaurin) and physiology (Keill, Cheselden, Cheyne), which cemented the centrality of the mechanical design analogy in natural theology by convincingly reiterating and expanding the treatment of the natural world as a machine in various disciplines.[140]

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[133] Boyle extended the metaphor's utility by applying it to the human body (*Free* 37, 39-40, 93, 126). But he also maintained that humans cannot be reduced to machines, for while humans have a 'machinal part', they also have intelligence guiding it (*Free* 135).

Flexible and open, Boyle's clock metaphor reflected his resistance to the reification of concepts like natural law by expressing them through metaphor instead of logical syllogism. On flexibility, see Schoen. On the importance of Boyle's metaphors, see McGuire; Mulligan.

[134] Earlier users included Dante, Descartes, Philippe de Mornay, and John Robinson, see Dillenberger 115-116; Mayr, 'Mechanical' 2. On the wider importance of Boyle's use for natural theology, see Brooke and Hooykaas 16, 18. For the assumptions, implications, and saliencies of the clock metaphor in its various sixteenth- and seventeenth-century applications, see Brooke and Hooykaas 27-33; Dillenberger 115-116; Gascoigne 229; Haber; Laudan; Maurice and Mayr viii, 291; Mayr, *Authority*, 'Mechanical'; Schoen.

[135] On alternative natural theologies and on the success of Boyle's natural theology, see Mandelbrote, 'Uses'. On early modern natural theology generally, see Mandelbrote, 'Early'.

[136] Shapin, *Scientific* 13; Brooke and Hooykaas 16. Mechanical science's support of design is a scholarly truism, yet it was not the only cause of natural theology's seventeenth-century flowering: on the psychological causes, see Brooke and Hooykaas; on the social and political, see Gascoigne; on the economic, see Jacob, *Newtonians* 240-243. Alternatively, Charles Raven emphasizes the importance of organic metaphors from Ray to Paley. For a balancing of mechanical and organicist metaphors in seventeenth-century natural theology, see R. Olson.

[137] Brooke and Hooykaas 15; Haber 9, 18; R. Olson 3.

[138] On the inextricable connection of natural theology and science in the early modern period, see Dixon; P. Harrison, '"Science"'.

[139] On Newton's relationship to religion and natural theology, see Dillenberger; Gascoigne; Odom 536.

[140] These authors disregarded or transformed elements of Newtonian philosophy in order to make it serve natural theology. Across the board, they ignored the fact that Newton began his scientific inquiry with the assumption that God actively intervened in the universe, see Gascoigne; Gillespie, 'Divine' 218; F. Gregory 369-370.

The shift toward mechanical metaphors in theology and science did not arise in a vacuum, but was supported by technological development.[141] Recent scholars have studied the most basic, and mutually-constitutive relationship between technology and mechanistic science: the 'material and intellectual manipulation' (Meli 19) of simple machines was the foundation of seventeenth-century mechanics.[142] Mechanical philosophy also grew out of the process of developing instruments, first mathematical and then later scientific, experimental ones.[143] Once complete, these instruments—like telescopes, thermometers, and clocks—directly assisted the endeavours of philosophers to measure the world while they also corroborated the mechanical view of nature by offering 'tangible proof, more impressive than any theory, that the natural universe of physics and biology was susceptible to mechanistic explanation'.[144] In this mutually beneficial relationship, once mechanistic science had become a relatively complete theory through the instrumental gathering of enough evidence, it became the framework for the technological developments of the Industrial Revolution.[145] Thus the mechanization of the design argument, and with it the thought of scientists, was due not only to shifts within abstract thought, but to the concurrent technological development of mathematical and scientific instruments.

Yet this mechanization was neither inevitable nor instantaneous. Blossoming into a peculiarly British form hardier than its continental cousins, natural theology emerged as an independent genre around the end of the seventeenth century, concerned specifically with presenting nature's evidence for God's existence and character.[146] But Boyle's mechanical metaphors were not the only style of natural theology available. Of his most immediate and important successors, John Ray favoured organic metaphors while William Derham favoured mechanical. At first, Ray sounds like Boyle, comparing design in nature to the design in human artefacts and its implication of 'some intelligent Architect or Engineer' (30), pointing to an artificer's skill in the variety of ways clocks, pumps, mills, and granadoes work (35, 367). But, preferring the wonder of organic physiology and anatomy because they offered

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[141] Traditional intellectual historians ignore the technological context, see Koestler; Koyré; Westfall. On the common sense expectation that the technological context would produce mechanistic science, see D. Price.
[142] Meli.
[143] Bennett.
[144] D. Price 9. Shapin and Schaffer's now classic *Leviathan and the Air Pump* (1985) focuses on a specific technology and its role in the development of the mechanical philosophy of specific philosophers. D. Price argues that mechanism triumphed over vitalism because we continue to intervene in nature through mechanical technology.
[145] On mechanistic science resulting in the Industrial Revolution, see Jones, *Industrial*; Mokyr, *Gifts*; Stewart 394.
[146] This peculiar Britishness was recognized by continental contemporaries, see Gordon 82; as well as later scholars, see Brooke, 'Why'; Brooke and Hooykaas; Dillenberger; Gillispie; Jacob, *Newtonians*; Lemahieu 39-42; R. Olson 6.

the most accessible and compelling evidences of design, Ray introduces and then emphasizes other metaphors in *The Wisdom of God Manifested in the Works of Creation* (1691).[147] He attacks reductive physiology and cosmology: 'so are there many *Phaenomena* in Nature, which being partly above the Force of these *mechanick Powers*, and partly contrary to the same, can therefore never be salv'd by them' (43).[148] For Ray, 'the Body is but the Machine or Engine, the Soul that *ἐνδόν τι*, that actuates and quickens it' (396). In contrast, Ray's friend, William Derham, worked entirely within the framework of Boyle's watch analogy, drawing on the increasing scientific mechanization of nature.[149] In *Physico-Theology* (1713), Derham assumes the mechanical design analogy, frequently invoking clocks and machines after describing a natural structure or process. About the atmosphere, he asks: 'Who would not rather, from so noble a Work, readily acknowledge the Workman, and as easily conclude the Atmosphere to be made by GOD, as an Instrument wrought by its Power, any Pneumatick Engine, to be contrived and made by Man!' (25-26). Eliding nature and artifice, Derham claims that the only difference is in the perfection of nature compared to the faultiness of the human arts.[150] Although Ray's work continued to be popular, indicating that mechanistic science did not immediately produce a monolithic mechanical design argument, Derham's fully mechanical style of natural theology ultimately triumphed by the beginning of the eighteenth century through the victory of mechanistic science over Aristotelian organicism.

With Ray and Derham, natural theology reached a 'qualitative high point'—and there was nowhere to go but down.[151] By the end of the eighteenth century, changes in the British intellectual, political, and scientific climate had indirectly undermined natural theology: Joseph Priestley's attempted shanghaiing of science into the service of a dissenting religious materialism raised Anglican suspicions of science, the new association of clock metaphors with rejected political absolutism led to the waning of mechanistic discourse, and the deistic natural theology of William Wollaston's *The Religion of Nature Delineated* (1722) cast suspicion on design arguments despite Joseph Butler's reply in *Analogy of Religion, Natural*

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[147] On Ray's preference for physiological wonder, see Brooke and Hooykaas 28; Gillespie, 'Divine'; Mandelbrote, 'Uses'. On the relationship of organic and mechanistic imagery in Ray's work, see R. Olson.
[148] On Ray's organicism, see Raven.
[149] Earlier in his career, Derham wrote an entire volume on horology entitled *The Artificial Clockmaker: A Treatise of Watch and Clock-Work* (1696).
[150] *Physico-Theology* 214, 226, 264-265, 268, 356. Two years later, his *Astro-Theology* (1715) uses the same tropes to treat astronomy: 'When we see divers Pieces of curious Device and Workmanship to bear the same marks of Art, to have the same masterly strokes of Painting, Clock-work, Architecture, &c. we conclude with great reason such Pieces were made by the same skilful Hand' (120-121).
[151] Pelikan 21.

and Revealed (1736).[152] But natural theology also suffered direct philosophical assaults in David Hume's *Dialogues Concerning Natural Religion* (1779) and Immanuel Kant's *Critique of Pure Reason* (1781) and *Critique of Judgment* (1790). Attacking the design analogy's logic, Hume denied that cause is inherently connected to effect. Attacking its aptness, he denied similarity between God and man and between nature and machines (*Dialogues* 81, 86-87). Attacking it through its entailments, he further emphasized the dissimilarity by presenting human design as an incredibly faulty process, which no Christian would want to project onto God (75-77). Thus, using its own analogies and metaphors, Hume denied that natural theology could establish the God of Christianity in his usual perfections, although he allowed a curtailed natural theology if it meant merely that '*the cause or causes of order in the universe probably bear some remote analogy to human intelligence*' (138). Like Hume, Kant criticized the co-option of natural theology into an explicitly theistic Christianity: 'the proof could at most establish a highest architect of the world, who would always be limited by the suitability of the material on which he works, but not a creator of the world, to whose idea everything is subject' (*Pure* A627). He also elaborated a lesser-known criticism: the *telos* observed in nature only really exists in the 'constitution of our cognitive faculties' and thus will always be subjective, not objectively true (*Judgment* 311). Yet it is easy to exaggerate the immediate impact of these attacks on natural theology. While they are now placed in the pantheon of philosophical greats, Kant was not popular in England until the middle of the nineteenth century and Hume's anti-natural theological work was not canonical for several decades, his immediate historical successors reading him rather as a historian than a philosopher.[153] Their attacks are, indeed, logically damaging to natural theology, but they did little damage to it historically, as it continued to have enormous power, especially in England, through the next century.[154]

Paley's *Natural Theology* had much to do with this success, presenting the design argument's most familiar form in 1802. While it reiterates the mechanical natural theological tradition of Boyle and Derham, this most famous of Paley's works also re-formulates that tradition according to his own technological context, ultimately creating a natural theology

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[152] On Priestley, see Knight 8-19. On absolutism and mechanical metaphors, see Mayr, *Authority*.
[153] On the British discovery of Kant, see Ashton 1-5. On Hume's position with his contemporaries and immediate successors, see Gascoigne 231; Knight 26.
[154] For the false assumption that these attacks brought the end of an intellectually-respectable natural theology, see Dillenberger 155; Guyer; Hurlbutt 169. On natural theology's continued power, see Arieti and Wilson 239; Brooke, *Science* 209; Ellegård 115-117; Hurlbutt 170.

for and by the Industrial Revolution.[155] He deploys mechanical metaphors in his design argument in two phases: first in his presentation of the design analogy itself and then in his presentation of nature as bearing design. Mechanical metaphors are thus involved in the argument *from* design, the actual theological apologetic argument for God's existence, and in the argument *to* design, the demonstration that design really does exist in nature.[156] Opening the text, Paley lays out his version of the Boylean clock analogy: a stone found on a heath can be attributed to chance, but a watch found on a heath must be attributed to an intelligent, designing watchmaker 'who formed it for the purpose which we find it actually answer; who comprehended its construction, and designed its use' (7-8). Simply put, 'there cannot be design without a designer; contrivance without a contriver; order without a choice' (12). Repeating the central metaphor of a well-established tradition, Paley, a consummate rhetorician, devotes his first six chapters to elaborating in detail the meaning of the mechanical design analogy by carefully analysing the qualities and attributes he projects from the human base to the divine target.[157] Paley uses the clock, however, to stand for machines generally, like 'telescopes, stocking-mills, steam-engines, etc.' (40), rather than mapping the specific qualities of the clock onto nature or of the horologist onto God. Paley's decision to stick with the clock instead of using newer industrial technologies like steam engines as the emblem for the design argument is probably due to the relative ubiquity and familiarity of clocks over steam engines in 1802, as well as the need to locate his work firmly within the natural theological tradition.[158]

But the clock analogy also served as a transition point from which Paley could introduce metaphors based on contemporary industrial technologies into his argument *to* design. After elaborating the clock analogy, Paley plunges into describing specific natural phenomena, consistently presenting them through mechanical metaphors. The heart is a pump and the blood vessels are pipes; muscles are the mechanical wire and strings like those of puppets. He uses 'a stocking-loom, a corn-mill, a carding-machine, or a threshing-machine', technologies of the Industrial rather than Scientific Revolution.[159] Born in 1743, Paley grew into adulthood with the Industrial Revolution. While writing *Natural Theology*,

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[155] On Paley's natural theology for and by the Industrial Revolution, see Gillespie, 'Divine'. Scholars disagree on Paley's relationship to the tradition of natural theology: some see *Natural Theology* as merely a 'resurrection' or an 'epilogue' (Hurlbutt 170; Mayr, *Authority* 123), but others recognize that it 'invigorated and reinforced' the tradition (Lemahieu xi) by making it relevant to a wide range of contemporary discourses (Eddy, 'Rhetoric'; Gillespie, 'Divine'; O'Flaherty, 'Part 1').
[156] On the argument *to* and the argument *from* design, see McGrath 53.
[157] On Paley as rhetorician, see Eddy, 'Rhetoric'; O'Flaherty, 'Part 1'.
[158] Knight speculates that clocks were more familiar than steam engines (30).
[159] Paley 11, 52, 69, 82.

he lived at Bishop Wearmouth, near Sunderland's successful shipbuilding industry, where he studied the bones from his dinner for contrivance, discovering that the backbone of a hare was built on the same principles as the bridge over the Wear River (Clarke 46, 52; Paley 59). In this second phase of Paley's application of mechanical metaphors, he shifts the natural theological tradition by building his argument on the 'absolute identity' of industrial machines and physiological machines, according to Neal Gillespie.[160] Paley raised what had been metaphors into definitions as physiological structures were not just similar to, but identical with other machines. In using the clock analogy, Paley placed himself in the tradition of Boyle, Newton, and Derham, but he also renovated the way nature was represented as bearing design. He thus made machines important to natural theology as the source for both linguistic and conceptual metaphors. By basing them on industrial machines, Paley helped natural theology survive beyond the decline of mechanistic science—and on into the nineteenth century. Reinvigorating natural theology, Paley's mechanical metaphors depended on the positive connotations of machines, erecting the structure within which nineteenth-century natural theology grew. Thus by 1802, the mechanical—indeed industrial—design analogy had come to form the core of natural theology.

Mechanical Metaphors in Nineteenth-Century Natural Theology

In discussing metaphor theory above, I argued *a priori* that the design analogy is a species of conceptual mechanical metaphor and that rhetorical mechanical metaphors buttress the design analogy. But my last section argued for the historical contingency of this relationship, tracing its development up to 1802. So did this relationship continue? Although demonstrating the cultural relevance and importance of 1830s natural theology, scholars have largely ignored its technological context. Only Gillespie discusses natural theology's technological tropes, claiming that while 'Paley had tied his natural theology to a mechanistic imagery', these mechanical metaphors 'for both professional and ideological reasons, rapidly lost [their] appeal among those who in the new century took charge of natural theology in Britain' ('Divine' 229). But Gillespie's widely-accepted claim seems untenable to me when the base of the metaphor—mechanical technology—was receiving increasing attention and acclaim.[161] So I ask again, did design remain conceptually mechanical in the 1830s?

[160] Gillespie, 'Divine'.

[161] For its acceptance, see Brooke, *Science* 194-196; Brooke and Cantor 191; O'Flaherty, 'Part 1' 23. For implicit corroboration, see R. Olson.

Assuming that linguistic metaphors indicate the presence and shape of conceptual metaphors, I will answer this question by tracing the linguistic or rhetorical instances of machine and engineering tropes in self-conscious, applied natural theology as well as in the philosophy of natural theology from this often-forgotten decade.[162]

Establishing natural theology's mechanical shape in the early nineteenth century, I will also show how mechanical metaphors became richer and more flexible, following and facilitating the flexibility and diversity of natural theology itself. Instead of being statically cemented in the mechanistic science of the Scientific Revolution, mechanical metaphors were fluid and flexible in usage and significance, adaptable to the variety of forms natural theology took in the nineteenth century. There was no single, timeless, hegemonic mechanical metaphor. Structurally, mechanical metaphors worked differently, while functionally, they did different work. This flexibility, even multiplicity, facilitated the continued centrality of mechanical metaphors in nineteenth-century natural theology by helping it adjust to cultural changes. Providing a platform from which to discuss the relationship of natural theology to its technological context, this section outlines the role and implications of mechanical metaphors in nineteenth-century natural theology. First identifying ways they could vary, it then explores ways mechanical metaphors did vary as they appeared in the natural theology of the 1830s. Recognizing the impossibility of generalization across such a varied group of texts, I take each individually, ultimately revealing how mechanical metaphors flexed to fit within a wide range of natural theologies.

In some ways, Gillespie is right about mechanical metaphors in the early nineteenth century: criticism did complicate their appeal. Outside theology, they were attacked for being inapt and harmful: the mind is not assembled like a machine but grows like a plant (inapt), while treating animals as machines in the Cartesian manner leads to animal mistreatment (harmful).[163] Inside theology, they also came under scrutiny. The mechanical design analogy was inapt because method can only be traced entirely in human arts but not in nature.[164] It was ineffective because unreached peoples did not recognize design when presented with a watch.[165] It was inappropriate because it turned God into 'a chamber artizan, composing and compounding eyes'.[166] But the biggest problem was its vulnerability

[162] Using linguistic as evidence of conceptual metaphor is especially evident in the continuing work of major thinkers within CMT, including George Lakoff, Mark Johnson, Mark Turner, and Zoltán Kövecses, who find the empirical evidence for their theories in languages and literatures from a range of cultures.
[163] Turton 92-95; Drummond 12-14.
[164] Jobert 26-28.
[165] Irons 122-127; Ensor 17.
[166] Ensor 21.

to hijacking by deists or dissenters.[167] Some blamed deistic and naturalistic determinism on the representation of the animal or human body as a machine determined by its mechanisms.[168] And as mechanical metaphors were connected with determinism and determinism with radicalism and radicalism with the French Revolution, this hesitance about the central metaphor had a political as well as a religious motivation.[169] Some blamed deism on design's presentation of God as a creator who set spinning a perfectly-designed, self-adjusting mechanical world independent of his action.[170]

Yet, while a few natural theologians took heed by omitting mechanical metaphors, most continued to use them, but more carefully and discriminately, aware of the flaws in and risks with the mechanical design analogy.[171] This continuance suggests that other powers of the metaphor trumped the risky ones. In the 1830s, mechanical metaphors accomplished a variety of often overlapping functions in natural theology.[172] Most basically, they served as the root metaphors of an inherited scientific paradigm and as an explanatory device reinforcing perception of design. But there were others. Expanding the taxonomy of functions, this section will create categories through which mechanical metaphors in nineteenth-century natural theology can become visible. Although far from comprehensive, my list includes several categories:

> **Relating to the design analogy**: mechanical metaphors could *reinforce the design analogy* by presenting nature as resembling the artisan's designed objects. Mechanical metaphors could *explain the psychological process* involved in the design analogy, with theorists suggesting that mechanical metaphors were necessary elements in the acquisition of the design analogy as a mental category. They could help authors *articulate which kind of evidence* was the most apologetically

[167] Brooke and Cantor 192; for that fear's historical precedent in Joseph Priestley, see Corsi 27, 145; Knight 8-19.
[168] For a nineteenth-century example, see Copleston 8; for comments, see Topham, 'Science and Popular' 418.
[169] For these connections, see Gillespie, 'Divine' 227.
[170] Brooke and Hooykaas 16; Fyfe, 'Reception'. This conception of the relationship between natural theology, deism, and the mechanical metaphor persisted through the 1970s, with reiterations by historians like Stephen, Burtt, Koyré, Butterfield, and Westfall (O'Flaherty, 'Part 2' 134; Osler, 'Religion' 2). Although recently challenged by Brooke ('Why' 58-60), this has also become a major historical metanarrative to explain secularization, see M. Buckley for an example.
[171] John Kidd omitted mechanical metaphors in his Bridgewater Treatise on *On the Adaptation of External Nature to the Physical Condition of Man* (1833), an omission possibly linked to Kidd's failure to offer a logical argument, since he believed that atheism involves intellectual absurdity (x).
[172] On the multiplicity of functions and meanings of mechanical metaphors in the sixteenth and seventeenth centuries, see Dillenberger 115-116; Laudan 77-89; Mayr, 'Mechanical'; Ruse, 'Robert' 581-595.

convincing. And, finally, once established, they could *glorify God* by contrasting God's creations with humanity's.

Serving scientific purposes of natural theology: in its *explanatory* function, mechanical metaphors could map physical or process qualities from the source (the machine) onto the target (body, universe, origin of species) in order to explain physical phenomena in a comprehensible way. They could *represent scientific conservatism* as more stable and tenable than new theories for natural theology. Finally, mechanicism had become *conventional language* in physics and mechanics inflecting treatments of natural objects and processes.

Constructing knowledge for various audiences: underlying both apologetic and scientific purposes of natural theology, mechanical metaphors in their epistemological functions could shape or present what it meant to know something. Mechanical metaphors and 'design discourse' could be a *leitmotif or invoked discourse* without a specifically logical purpose. They could *establish the legitimacy of an area of study* for natural theological purposes by connecting it with traditional natural theology. In this function, traditional natural theology was presented as depending on mechanical metaphors and a new science or theory was shown to dovetail with it through the applicability of mechanical metaphors within it. But they could also *highlight the innovation of an author* in his application of mechanical metaphors in unusual or unexpected ways. They could *appropriate new sciences* that threatened to harm natural theology, like evolution or psychology. Finally, they could *make a nebulous target discrete*, especially in the conceptualization of new sciences.[173]

Justifying or theorizing technology and invention: the common device of contrasting God's creations with humanity's in order to glorify God connected natural theology with technology and industrialism directly, leading to a theorization of invention and technology in terms of natural theology and theistic religious belief. Thus formulated, technology and industry could be invoked as direct evidence of God's creation of the world. Natural resources useful for industrialism could be direct

[173] On the vaguer term being made more concrete and coherent by the other, see Bowdle and Gentner 187-198; Lakoff and Johnson 26-27, 112, 264.

> proof of God's benevolence. Reversing the direction of the design analogy, human inventions could be patterned on God's designs in nature.

Thus mechanical metaphors served theological, scientific, epistemological, and political/philosophical functions in nineteenth-century natural theology. But although outlined distinctly, the functions intertwined within a single text and even within a single instance of the metaphor.

While they did different work, they also worked differently. Each mechanical metaphor varied in specificity, both for the source and target. The mechanical source could be general, as 'machine' or 'mechanism', or specific, like clocks, telescopes, cameras, mills, or factories.[174] As the source became more specific, the features mapped onto the target also became more specific, allowing greater control to the author. Yet using a specific machine could make the metaphor outmoded when technology advanced, dragging natural theology down with it.[175] The same generality-specificity scale was evident in the target onto which the mechanical source was mapped. Mechanical metaphors could represent the whole cosmos, or describe only an aspect of it. An entire animal could be a machine, or a single structure within it was mechanical. Most objections were to metaphors which reduced a whole, whether the universe or a human being, to a machine, implying determinism or materialism. Although each instance of a metaphor registers differently on this scale, they clustered at different points on it through time. For Newtonians, mechanical metaphors often described the structure of the whole universe. In the nineteenth century, two groupings emerged. Mechanical metaphors described the workings of particular parts of animal physiology and anatomy for writers like Boyle, Paley, and Bell in his *Treatise on Animal Mechanics* (1817). But they also described the universal process of how natural laws worked in the government of the universe for Whewell and Babbage. In both groups, there was a trend toward limiting mechanical metaphors. With the laws of nature, they accounted for mass and motion, but not the source of mass or motion. With animal bodies, they described parts of the body, but could not account for muscular energy or for volition. Thus limited, they were safe to apply to processes, functions, or structures.

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[174] Sometimes they are so specific as to use particular manifestations or parts of those machines, like corn-mills or fly-wheels, or to use a single technology, like Smeaton's Eddystone lighthouse (Kidd 2:165-167).

[175] Although not expanding on it here, the selected base can also excite the reader's class prejudices: a scientific machine seems higher class while an industrial machine seems lower, influencing the usefulness of the metaphor.

The various functions and functionings of mechanical metaphors layer over the 'styles' of natural theology in the nineteenth century to create a complicated picture.[176] Of the multiple ways natural theologies diverged, three are particularly important for mechanical metaphors: the educational intent, the apologetic status, and the type of evidence. The remainder of this section will use these three topics as spotlights to illuminate the contours of the mechanical metaphor's flexibility, tracking the ways its authors fit their metaphors to their understandings in those three categories. First, although natural theology's nominal aim was theological, only slightly less important was its educational purpose as popular science. Thus its tropes could serve one objective, the other, or both. Second, there was major disagreement about natural theology's apologetic power. A strong evidentialist natural theology had declined in the face of epistemological challenges while a softer natural theology which corroborated, rather than proved, Christian doctrines grew.[177] If natural theology was corroborative rather than logically coercive, then mechanical metaphors were more valuable for their affective than their logical-predictive functions.

The third, evidential type, deserves more attention and will serve as the general frame for my detailed treatment of natural theology in this section. Three evidential strains coursed through 1830s natural theology: contrivance, adaptation, and the laws of nature. Paley's focus on contrivance in 1802 produced his systematic and rhetorically-essential mechanical metaphors. By definition, contrivance contains within it the idea of adaptation of means to ends, of fitness to accomplish certain goals, a teleology reinforced by mechanical metaphors as machines are clearly made for specific purposes. While many of his successors continued to draw their evidences from contrivance, they framed it in terms of adaptation in order to meet perceived cultural needs.[178] In that it clearly implies design, contrivance points to the *existence* of a divine designer. But adaptation focuses on the qualities of the contrivance, yielding the *character* of the designer. At this historical moment, the charitable assumption that everyone believed in a deity focused natural theology rather on God's character than his existence, evidenced in the sub-title of the Bridgewater Treatises: 'On the Power, Wisdom, and Goodness of God Manifested in the Works of Creation'.[179] Indeed, an author's place on the continuum between contrivance and adaptation often registers his perception of natural theology's apologetic power. Yet adaptation has a broader application than merely

[176] I borrow 'styles' from Osler's conception of 'styles of science' in comparing Gassendi and Descartes (*Divine*).
[177] Corsi 68; Brooke, 'Indications'.
[178] On adaptation, see Ospovat, 'Perfect' 33.
[179] On this assumption, see Corsi 64.

expressing the quality of contrivance. Where a contrivance is a physical, concrete object that could be described mechanically, adaptation is about relations: of means to ends, of parts to each other, of the fitness to do good, of animal and environment, and of the laws of nature to each other, to living beings, and to the human mind. So where mechanical metaphors supported contrivance by tracing structure, they could also support adaptation by concretizing relationships.

The remodelling of mechanical metaphors to fit adaptation appears in the invocation yet renovation of Paleyan mechanical metaphors to legitimate new sciences for natural theology in William Prout's Bridgewater Treatise on chemistry and Thomas Chalmers's on psychology and sociology. Exhibiting the evidential flexibility of mechanical metaphors, these invocations also fulfil an epistemological role in natural theology's educational function. In the first systematic chemico-theology, *Chemistry, Meteorology, and the Function of Digestion Considered with Reference to Natural Theology* (1834), Prout borrows a specific metaphor from Paley to defend chemistry's usefulness for natural theology (11).[180] Prout compares the chemical observer to Paley's '"unmechanical looker-on"' who recognizes design because of the useful change in materials without knowing how the machinery works. Likewise, the means are unknown in chemistry, but the useful results are clear—and so, therefore, is design.[181] But knowing that mechanical identity is central to Paley's metaphors, Prout uses the factory metaphor as a departure point and mechanical identity as a point of comparison for his chemico-theology. Recognizing that chemistry is non-mechanical by definition and that design is not necessarily mechanical (Introduction), Prout continues to use Paleyan mechanical metaphors in explicating the basics of chemistry: molecules are like small machines adapted to their functions (85-89), the mechanical movement of the earth and atmosphere contributes to the balance of evaporation with condensation (290), and the mechanical parts of the body are subservient to the chemical (540). However, since he defines design in terms of adaptation rather than contrivance (Introduction), Prout uses these metaphors to highlight adaptation: in the two latter examples, the mechanical parts are actually adapted to the chemical, which are adapted to the good of beings. Because chemistry is non-mechanical by definition, these mechanical metaphors do not map the qualities of physical mechanical construction but those of utility and purpose.[182] Despite the evident problems with explaining chemistry by mechanical metaphors, Prout does so anyway,

[180] On Prout's chemico-theology, see Brooke and Cantor 323-331.
[181] Paley 52-53; Prout 9-10.
[182] Prout also recognizes that the materialistic salience of necessity transferred from machines to nature weakens the devotional punch of the mechanical design analogy (11-12).

using Paley's own metaphor to show how Paleyan and chemico-theologies are mutually-reinforcing evidential strands, and updating mechanical metaphors by applying them to adaptation in the process.

Considering a very different science, Chalmers's *On the Power, Wisdom, and Goodness of God as Manifested in the Adaptation of External Nature to the Moral and Intellectual Constitution of Man* (1833) offers a sociological natural theology founded on the mutual adaptation of society and the individual through the human conscience. The only Bridgewater author 'who occupies a territory which he may call his own' ('Bridgewater' 4), Chalmers establishes psychology's apologetic and scientific legitimacy by presenting it in terms of traditional natural theology founded on material sciences:

> while their provinces respectively are to trace the hand of a great and good Designer in the mechanism of the heavens, or the mechanism of the terrestrial physics, or the mechanism of various organic structures in the animal and vegetable kingdoms; it will be part of ours, more especially, to point out the evidences of a forming and presiding, and withal benevolent intelligence in the mechanism of human society. (1: 9)

This is not casual invocation of mechanical design discourse: mechanical metaphors configure both his philosophical understanding of design and his presentation of psychological data. Philosophically, Chalmers uses the entailments of the mechanical design analogy to articulate his conception of its most effective form around two poles. First, he reasons that since man's 'manifestations of skill are most apparent' in the arrangement of the 'natural mechanism' rather than in the laws by which it works (1: 16, 22-23), so it is with the divine Creator. Second, Chalmers recognizes that while design is easier to perceive in more complex arrangements, a wiser design is a simpler one (1: 14-15). Thus the best evidence for God's existence contradicts that for his wisdom, a contradiction forced on Chalmers by the mechanical design analogy, which he still neither abandons nor limits. He uses mechanical metaphors in his concretizing description of the 'Moral and Intellectual Constitution of Man' and the adaptations evident therein. The conscience is like 'the regulator of a watch' (1: 64), the relationship between the individual mind and society is an 'adaptation in the mechanism of human society' (1: 170), while the economy is 'a complex inanimate machine' whose controlling hand, per Adam Smith and Robert Malthus, is the independent individual's values controlling him as 'a fly in mechanics regulates' a steam engine (2: 47).[183] These metaphors serve Chalmers's apologetic purposes by justifying the study of mind and by making the conscience appear to bear design, his educational goals by making this nebulous thing more tangible, and his epistemological needs by constructing the mind as something knowable.

While Chalmers and Prout depended philosophically on invoking the mechanical tradition to legitimate new sciences, other Bridgewater authors used mechanical metaphors in a primarily explanatory way.[184] Bell's *The Hand: Its Mechanism and Vital Endowments as Evincing Design* (1833) is clearly devoted to educating the audience as much scientifically as religiously.[185] Knowing about the dangerous associations of mechanical metaphors within anatomy and physiology, Bell carefully articulates the role of mechanism in physico-theology, insisting that seeing the body as a machine does not lead to atheism when done correctly.[186] Philosophically, Bell maintains that only part of the body is mechanical and that by studying it, the observer recognizes how the body's machinery corresponds to external nature and its laws, adaptations reflecting the goodness of God's design.[187] Apologetically, mechanical contrivance is secondary to animal vitality as evidence of design.[188] Yet, rhetorically, machines are useful illustrations because 'level to our comprehension' (216). Bell, like Paley, treats the 'animal machine' as a machine in its own right. In his explanations, he uses a specific man-made contrivance to explain a principle of mechanism, then shows how an anatomical structure works by that same principle. For example, the animal frame works because its materials relate properly to the force needed to raise a certain weight a certain distance as with wheels, levers, and scaffolding.[189] Specific man-made machines are metonymic illustrations, rather than metaphors, used to demonstrate that anatomical structures fit within the category of the machine. While his treatise abounds with

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183 Chalmers carefully applies the design analogy to society: 'When we behold the workings of a complex inanimate machine, and the usefulness of its products—we infer, from the unconsciousness of all its parts, that there must have been a planning and a presiding wisdom in the construction of it. The conclusion is not the less obvious, we think it emphatically more so, when, instead of this, we behold in one of the animate machines of human society, the busy world of trade, a beneficent result, an optimism of public and economical advantage wrought out by the free movements of a vast multitude of men, not one of whom had the advantage of the public in all his thoughts' (2: 35).

184 Topham, 'Science and Popular' 399, 414-418.

185 Engaged at the front lines of scientific education, Bell lectured on anatomy to medical students and popularly for Brougham's Society for the Diffusion of Useful Knowledge, eventually publishing his popular lectures on *Animal Mechanics* (1827-29) with the SDUK. On Bell and scientific education, see Jacyna; Topham, 'Science and Popular'.

186 On Bell's awareness of their danger, see Topham, 'Science and Popular' 418.

187 *Hand* 3-11.

188 *Hand* 1, 45, 182, 186, 274.

189 *Hand* 5. Later he elaborately compares an arm swinging a hammer and a windmill, flywheel, stamping engine, and printing press to show that the arm 'corresponds with other mechanical contrivances' in the 'same interchanges of velocity and force', which match the universal mechanical conditions (136-38).

such explanations, Bell sees animal vitality as the foundation for his argument. Thus his apologetic and his explanatory purposes are in tension: his careful apologetic restriction of the machine's role is sustained throughout the treatise, while his educational goals cause him to emphasize mechanical illustrations and discourse because of their understandability.

While multiplying Bell's subject matter, assumptions, and goals, Roget's *Animal and Vegetable Physiology Considered with Reference to Natural Theology* (1834) uses mechanical metaphors in a primarily philosophical way to elaborate design. Like Bell, Roget includes the mechanical as one function within the animal body, to which he devotes his entire first volume of six-hundred pages while he crowds the non-mechanical vital, sensorial, and reproductive functions into the second volume.[190] But where Bell uses very specific mechanical illustrations, Roget does not. He relies heavily on man-made contrivance to outline natural theology's purpose and method: 'the evidence of design and contrivance in the works of nature carries with it the greatest force whenever we can trace a coincidence between them and the products of human art' (1: 28). But while he compares water bugs with boats, the heart with a hydraulic engine, a torpedo with a galvanic battery, and the eye with a *camera obscura* in his general introduction (1: 29-32), concrete mechanical metaphors are absent from his treatment of concrete nature. He speaks vaguely of mechanism or machinery in the introductions to each section, but not when describing actual animal bodies in detail.[191] He even perceives a limit of the mechanical metaphor's aptness: man-made machines transfer force from one source or direction to another but animal machines contain their own motive force (1: 124-128), emphasizing that no human is capable of the contrivance visible in nature.[192] He never ignores this distinction, even for illustrative detail, except with simple machines, like levers, fulcra, and wedges. Yet admitting the difficulty of tracing the workings of animal machinery, Roget emphasizes contrivance as the starting point which when followed faithfully results in knowledge of adaptation and therefore in knowledge of the wisdom, power, and goodness of 'the great Mechanist of the living frame' (1: 33-34, 31).

[190] On his educational goals, see Roget 1: ix-x. Roget defines the 'mechanical' as 'changes which consist in sensible motions of material bodies' (1: 6). A bit of a polymath, Roget was familiar with human contriving, working with Jeremy Bentham on a frigidarium and on utilizing London's sewage, associating with industrial magnates like John Phillips and Lovell Edgeworth, inventing a logo-logarithmic slide rule, communicating with scientific men like Babbage and Macvey Napier, and improving London's water supply with Thomas Telford, earning him a membership in the Institution of Civil Engineers (Murray).
[191] Exceptionally, he elaborates the eye as an optical instrument (2: 444-507).
[192] Roget 1: 21, 60-61, 125, 139-140; 2: 1-2, 458-459.

Although favouring adaptation over contrivance, many of the Bridgewater Treatises self-consciously located themselves within the Paleyan tradition and its mechanical imagery, rhetoric, and philosophy. Some, like Bell and Roget, multiplied examples of machines in nature, drawing on Paleyan contrivance, to serve their educational goals. Others, like Chalmers and Prout, used the Paleyan mechanical tradition to justify their disciplines for natural theology. All four used it to elaborate the design analogy. Each prefers adaptation or adapted contrivance as the best type of natural theological evidence, often rejecting the laws of nature as permissible evidence. By the 1830s, the Newtonian marriage of 'providential design and a law-abiding universe' (Gascoigne 246) in natural theology had disintegrated and the appropriateness of the laws of nature within natural theology became a fracture line within the Bridgewater Treatises, with authors taking a variety of positions. Chalmers and Kirby had inherited from Rennell the belief that research into the 'laws of nature' was symptomatic of attempts to make God unnecessary in the functioning of the universe (Corsi 51). Yet others, like Buckland and Whewell, actually incorporated the laws of nature into their natural theologies in a variety of ways, again giving mechanical metaphors a role to play.

Like Chalmers and Prout, Buckland legitimizes his science by connecting it with conventional, Paleyan natural theology, but diverges by including law as evidence. Assuaging anxiety about geology's threat to Christianity, Buckland's *On Geology and Mineralogy Considered with Reference to Natural Theology* (1836) openly makes mechanical contrivance essential to his paleo-theology, claiming that fossils show 'the same evidences of contrivance and design that have been shown by Ray, Derham, and Paley'.[193] Like Paley, he traces specific machines in nature: the Megatherium's tusks are like pick axes, its teeth are like 'rollers of a crushing mill', and its mouth is 'an engine of prodigious power' (1: 138, 148). Again, like Paley, he uses mechanical metaphors abstractly to express the design analogy: fossils 'afford examples of contrivance and design, as unequivocally attesting the exercise of Intelligence and Power, as the mechanism of a Watch or Steam engine, or any other instrument produced by human art, bears evidence of intention and skill in the workman who invented and constructed them' (1: 573). But Buckland adds geological law to contrivance as evidence, holding together increasingly divided major strands in natural theology.[194] Yet while Buckland presents the geological changes as subservient to

[193] See also 1: 96, 107, 311. For geology and Christianity in the 1830s, see, among others, Corsi 55; Gillispie; Klaver.
[194] For this division, see Brooke, 'Natural Theology and the Plurality' 227.

mechanical 'laws of matter and motion' (1: 49), he does not use mechanical metaphors to describe the orderliness and uniformity of geological natural laws. Aware of their apologetic and explanatory value, Buckland's omission of mechanical metaphors raises the question of their appropriateness to express the system of the laws of nature. Fighting shy, Buckland, sidesteps the objection that applying mechanical metaphors to the universe precludes God's further intervention and makes humans powerless products of that universal machine.

'The most comprehensive' ('Bridgewater' 5), popular, and intellectually rigorous Bridgewater Treatise, Whewell's *On Astronomy and General Physics Considered with Reference to Natural Theology* (1833), attempted to reorient natural theology by philosophically lessening its apologetic power and by incorporating the laws of nature into it, using mechanical metaphors in his philosophy, explanations, and epistemology to ease the change.[195] Whewell believed that natural theology was insufficient to produce conversion. Instead, he gave it a 'corroborative' or 'confirmatory' rather than 'demonstrative' function for religion.[196] For science, it could reassure readers that science was compatible with Christianity. Law was at the center of each of these endeavors. Confident that contemporary science's reduction of natural phenomena to 'a collection of facts governed by laws' fit with belief in God, Whewell uses the 'import and tendency' of those laws to verify a pre-existent understanding of God (3, 4). Suggestive and mediating, natural theology was thus not a theological *argument* for Whewell. Instead, in its 'suggestive role', it led to 'belief of a supernatural and presiding power' rooted more in perception and intuition than compelling logic (293-295).[197]

Whewell's rejection of demonstrative natural theology could easily have involved a rejection of mechanical metaphors because of their often logical, demonstrative function. Yet Whewell applies them in multiple ways, some traditional and some innovative. Like others, he uses a discourse of mechanism, like Topham's 'discourse of design', to make nature and its systems easy to understand: a different strength of gravity would render the universe 'like a machine ill-regulated' (43-44). Because he was a sophisticated thinker who selected his imagery carefully and knew the limitations of specific metaphors, Whewell's mechanical

[195] Although it has important continuities with the tradition (Yeo, *Defining* 30), it also breaks with it by rejecting utilitarianism (Brooke, 'Indications' 155; Yeo, 'William' 515) and by his refusal to borrow 'any of his views or illustrations from recent English writers on Natural Theology' (Whewell, *Astronomy* xiii).
[196] Brooke, 'Indications' 162, 164. While this sounds like a theology of nature, Whewell is offering a complex natural theology based on his philosophical program which maintained the 'impossibility of the progress of our knowledge ever enabling us to comprehend the nature of the Deity' (366). Philosophically, natural theology revealed the unity of truth without making religious knowledge dependent on scientific knowledge.
[197] On its 'suggestive role', see Brooke, 'Indications' 167.

discourse cannot be ignored.[198] Legitimating, Whewell uses mechanical metaphors specifically and elaborately to describe how the eye works according to the same laws as a *camera obscura*, designating the eye a machine by definition.[199] But he also switched up the mappings of mechanical metaphors. Examining the fitness of the yearly 'vegetable clock-work' to the solar system's timing (22), Whewell employs both the salience of time and of Paleyan contrivance to express this adaptation (29-30). His work thus reveals the flexibility of mechanical metaphors by applying them to a novel target, projecting novel qualities onto that target, and only indirectly integrating the metaphor into apologetics.

Yet while often absent from the surface of Whewell's work, mechanical metaphors function in the depths. His discipline of physics was conceptually structured by mechanics and its mechanical metaphors, so they constituted his scientific thought.[200] They also structured his apologetics by expressing the adaptation between the laws of nature and specific objects, structures, and organs, plus nature's overall adaptation to the good of living beings. Discussing the adaptation between organic and inorganic nature, Whewell queries 'who constructed these three extraordinarily complex pieces of machinery, the earth with its productions, the atmosphere, and the ether? Who fitted them into each other in many parts, and thus made it possible for them to work together?' (141). Unlike other explanatory mechanical design discourse, Whewell's does not deploy the concrete, physical features of the natural objects. Instead, the metaphor projects a relationship, of the parts of a machine to each other, onto nature, which then supports the perception of design, and then of God. Thus, for Whewell, mechanical metaphors were not direct evidence of design, but a method for expressing the adaptation of a small part of nature to the laws of the universe, as machines do by definition. They even structure his explicit definition of adaptation as 'of construction to conditions' (29). Differing from some of his Bridgewater brethren, Whewell integrates laws of nature and adaptation as evidence of design, using mechanical metaphors to describe that adaptation.[201] Apologetically, these machine-structured demonstrations of adaptation would awaken the intuition of design latent in the human mind, rather than compel the mind by logical steps, for what 'habits of thought' can see machines and not infer design (146)? Yet, Whewell also recognizes problems with mechanical metaphors. While men take 'advantage' of laws and pre-existing materials to make machines, God creates both (359). From this

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[198] On his sophistication, see Ruse, 'Relationship' 505; R. Young 136. On his careful selection of images, see Whewell, *Astronomy* 6, 148-151, 359-361, *Indications* 90-91.
[199] *Astronomy* 128-137.
[200] Mechanical metaphors also shaped Whewell's thought on the economy, see Marsden, 'Progeny' 425; Wise and Smith.
[201] On Whewell and laws, see Brooke, 'Natural Law' 88, 'Scientific Thought' 47; Topham, 'Teleology' 151.

contrast, he concludes that 'we may and must, therefore, in our conceptions of the Divine purpose and agency, go beyond the analogy of human contrivance' (360). The contrast limits the rhetorical value of mechanical metaphors for serious science, for popular science, and for apologetics.[202]

In response to Whewell's critique of deductive, 'mechanical' philosophy, Charles Babbage's unauthorized *Ninth Bridgewater Treatise, a Fragment* (1837) uses mechanical metaphors to legitimate deductive thinking and mathematics for natural theology—and describes law through those metaphors in the process.[203] Assuming the validity of design, Babbage uses his calculating engine to revise the design analogy in order to assimilate a law-governed world with a miracle-working God, for he knew that 'visible forms make a much deeper impression on the mind than any abstract reasonings' (*Ninth* 142).[204] His calculating engine could be programmed to compute a certain table of numbers for a certain number of terms, but then to calculate the *n*th term according to a different formula. Thus what appears anomalous is actually a fulfillment of a pre-applied law (*Ninth* 33-49; *Passages* 93-99). So are miracles and geological changes. Beyond its law application, Babbage's metaphor is significant for its new and varied mappings. As part of the source of his mechanical design analogy, the calculating engine was cutting edge, where many of natural theology's other machines were older and possibly outdated technologies, and it was scientific rather than practical, securing it from low-brow, practical associations. In this context, selecting his own invention led to a more nuanced conception of the relationship between the designer and his design. Himself an inventor, Babbage jumps from the 'highest and best of human faculties' to the faculties of God (*Ninth* 23-24), suggesting that because the best human designers do not have to interfere with the workings of their machines, then to say that God must frequently interfere is to present a weaker conception of God.[205] Thus Babbage's answer to the question of miracles and successive stages of geology uses a new mechanical design analogy based on an innovative technology to mediate between new sciences and old natural theology, fulfilling primarily theological, not apologetic purposes. While he fearlessly used mechanical metaphors to describe the universal laws of nature, Babbage was also aware of the problems with them, hinting at the reason theologians had shied away from applying mechanical metaphors in discussing natural law. He follows his chapter that elaborates the

[202] He also limits the application of mechanical metaphors by flatly denying any natural theology based on presenting the solar system as a machine because it has no touching parts, necessities for mechanical action (*Astronomy* 148-149, 151-153).
[203] See Whewell, *Astronomy* 334.
[204] On the problem of miracles in the 1830s, see Cannon.
[205] Babbage, *Ninth* 24-25.

analogy with a chapter on how his views do not lead to fatalism.[206] Although inadequate, his discussion of fatalism right after his metaphor reflects the danger of mechanical analogies when the wrong entailments are elaborated.

Like Babbage's, other philosophies of natural theology also turned to mechanical metaphors to theorize design. Alexander Crombie, Henry Brougham, and George Crabbe codified the Paleyan contrivance version of the design analogy through mechanical metaphors. Fending off atheistic attacks, Crombie's *Natural Theology: Or Essays on the Existence of the Deity* (1829) carefully transfers a range of specific qualities from humanity's relationship to machines onto God's relationship to the universe. For example, reducing a machine's working to laws strengthens the conviction that mechanical skill was needed to arrange proximate causes (1: 218, 222, 463).[207] Unlike Babbage, Crombie does not care which machine is used, for all 'are mutually alike in the aptitude of the materials, in the curious construction of the parts, in the congruity of their arrangement, the harmony of their motions, and their concurrent operations towards the production of the effect' (1: 361). Accompanying his updated edition of Paley's *Natural Theology* (1836) coedited with Charles Bell, none other than Henry Brougham also published a theory of natural theology, defending it from scientific detractors. His *Discourse of Natural Theology, Showing the Nature of the Evidences and the Advantages of the Study* (1835) describes a natural theology that is entirely mechanical (28-39, 187-188), dwelling on the eye (28-32) and using the watch as an example (43-44). Tellingly, Brougham shows no evidence of feeling the need to justify a natural theology so heavily dependent on mechanical metaphors or identities, implying that this was a standard and accepted description of what natural theology was in 1835. Finally, Crabbe's *An Outline of a System of Natural Theology* (1840) seeks to demonstrate what Paley's design analogy assumes: that the adapted parts of nature 'occur without any associating physical law' (10-11). Mechanical metaphors structure his very thinking: it is unlikely that Crabbe would be discussing the independence of parts without the idea, based on mechanical technology, that something can be disassembled into independent parts which fit together.

Mechanical metaphors were also used to theorize natural theology based on law, as they did with Babbage. But this was a more complicated endeavour with less consistency

[206] *Ninth* 50-62.
[207] Here are some of the other projected features: reduction of wonder by familiarity damages awareness of design (1: 77-78); the agency required for contrivance is not in the inert material tools (1: 111-114, 127); the properties of matter cannot create the contrivance (1: 184-185, 218); chance could produce contrivance, but not a moving contrivance (1: 169); not knowing the means produces greater respect for the mechanist (1: 408, 420); moving powers reveal a designer because they stay within the 'limit of utility' and do not run over into evil (1: 440, 472-473); and the results and products of machines are foreseen by their designers (2: 175, 267).

among theologians. Baden Powell's *The Connexion of Natural and Divine Truth: Or, the Study of the Inductive Philosophy Considered as Subservient to Theology* (1838) actually backed off mechanical metaphors. His redefinition of design in terms of adaptation instead of *telos* (116-117) produces a seemingly equivocal inclusion of mechanical metaphors in his work. He suggests that 'the real question obviously refers to the machinery, not for the *work* it does, but for the *skill* displayed in its *construction* and *operation*; the proofs of which are unquestionably stronger, as it requires less manual interference' (292). Where Paley traces actual machines in specific natural systems, Powell allows abstract mechanical metaphors to describe the abstract structure of the laws of nature. For Paley, the salience of a machine included actual, physical mechanical structures and a designing mind behind them, while for Powell the salience is only of the designing mind. Yet, ambivalently he thought buildings or paintings provided as much evidence of design as machines did (135, 140) while also aware that 'the untaught mind' does not immediately infer a designing mind when it sees a machine (85). He offers two alternative metaphors for a new natural theology: an architectural metaphor and a legal metaphor. Causes and laws form 'a self-supporting equilibrium, like the stones of an arch' (108-109) while the existence of a good governor is known from the good and consistent laws in a country (199). This seemingly divergent attitude toward and use of mechanical metaphors is the product of his awareness of the instability and malleability of metaphors and analogies generally.[208] Thus Powell's work reflects not only the shift from contrivance to natural law, but also shows how mechanical metaphors had a complicated and chequered role in 1830s natural theology and its philosophy. That he continued to use them when he knew others were available reflects their power.

Indeed, while I have outlined the uses of mechanical metaphors in a systematic way, describing their specific and often intended functions and functionings, they were often used ambivalently. Where Powell was clear-sightedly ambivalent about mechanical metaphors, authors of applied natural theologies could also use them ambivalently because they were just so culturally-available. As a convenient resource within the stereotyped tradition from which they wrote, mechanical metaphors were not interrogated. In his corroborative theology of nature, *Celestial Scenery* (1838), Thomas Dick uses mechanical metaphors to describe

[208] Powell carefully investigated and rejected the chain metaphor for causation because it makes God a link in the chain (83-85), aligned natural theological analogical reasoning with the foundation of inductive science in analogy (75), and cast the Bible's language as poetic and metaphorical rather than literal (260).

specific parts of nature.[209] An applied but unsophisticated natural theology, Henry Fergus's *The Testimony of Nature and Revelation to the Being, Perfections, and Government of God* (1833) sees the mechanical design analogy as weak (14, 123), yet he elucidates the eye as an optical instrument (20-29) and uses machines as a light motif in presenting human anatomy (29-32) while the analogy conceptually structures his understanding of design (12-13). This ambivalence appeared also in the Bridgewater Treatises. William Kirby's *On the History, Habits, and Instincts of Animals* (1835) is more concerned with entomological detail than philosophical or rhetorical consistency so he jumbles mechanical metaphors into a bundle of contradictions. Concerning God's interaction with the universe, Kirby uses the clock analogy to defend God's action by physical causes but denies deist conceptions of the universe as a machine set in motion but not superintended by God (1: ciii; 2: 277-278), for example. Despite the philosophically and rhetorically unsystematic nature of these works, their seemingly unintentional use of mechanical discourse reveals that it had cultural currency in the mid-1830s natural theology. These objections to, omissions of, and ambivalences of and toward mechanical metaphors layered on top of their cultural ubiquity are shadows that make mechanical metaphors loom larger rather than smaller on the landscape of 1830s natural theology.

No matter the evidential type, the apologetic status, or the educational goals, mechanical metaphors appeared time and again at both the linguistic and conceptual levels of natural theology. And they needed significant flexibility to adapt to this variety. There was no static mechanical metaphor that mapped unchanging and coherent qualities from machines to nature. Instead there were shifts and variety in the way they were used, how they related to the design analogy, and in what qualities they projected and onto which targets. Indeed, their sources and targets did not stay still either. The meaningful features of machines changed, and so did mechanical metaphors. With these changes, it is impossible to see mechanical metaphors in nineteenth-century natural theology as tired carry-overs from mechanistic science. They are new metaphors inextricably linked to the changes in technology and the changing conceptions of and enthusiasms for machines. Rather than metaphors of the Scientific Revolution, these are metaphors of the Industrial Revolution. Even if mechanical metaphors no longer appealed to the scientific mind, they had incredible strength, riding on the fascination with technology in the popular consciousness. Mechanical metaphors were no longer primarily a predictive or a descriptive device. Instead, they were an interpretive one

[209] Dick 35-36, 46-47, 63, 292.

crafted for and by the techno-culture surrounding 1830s natural theology. The next four chapters will explore how this interpretive device was fashioned, investigating the meanings of machines and engineering, how they were constructed, and how they interacted with the design analogy.

CHAPTER 2

Understanding the Machine: Popular Technology, Natural Theology, and Comprehensibility

A decade after Paley published his famous version of the watch analogy, a Scottish missionary named John Campbell showed his pocket watch to a group of South African Bushmen and recorded their responses:

> I took out my watch, opened it, and held it before them; on observing its motion, they evidently concluded it must be a living animal, and my offering to hold it near their ears, to hear its sound, seemed to convince them it was some dangerous creature, by which I intended to injure them, for they almost overturned the hut in order to escape from the watch. On observing that their terror was no affectation but real, I left them, and carried the watch open to Makoon, which he and his men viewed from a little distance with fear and surprise. On offering to hold it near his ear, he shrunk back, but to display his courage before his people, he summoned up all his resolution, and ventured to listen to the beating of the watch. (325-326)[1]

Making a common move in the missionary enterprise, Campbell used this European technological object to attract the Bushmen's interest, to exhibit European supremacy, and as a preview of possible future ritual exchanges of objects.[2]

But when this story was told in Britain through the publication of Campbell's widely-read *Travels in South Africa* (1815), the anecdote took on a different significance: it stood as a test of the apologetic power of Paley's watch analogy on a control group of Bushmen.[3] In 1770, the arch-atheist and determinist Baron D'Holbach had predicted in his *Systeme de la Nature* that savages require 'ideas of human industry' in order to interpret a watch as made by a human. Otherwise, they would view it as a self-existent genius or spirit (Holbach 355). A new translation of D'Holbach's work in 1820 reminded theologians of this critique of natural theology at the same time that Campbell's story provided empirical evidence for

[1] On Campbell, see Comaroff and Comaroff; West.

[2] On the importance of objects in the missionary enterprise in South Africa, see Comaroff and Comaroff 183-192; West. For Campbell, such objects signaled European supremacy, but others hid them, afraid they might awaken native avarice (West).

[3] Powell observes that 'this example has, in fact, been much dwelt upon, and regarded as decisive against the efficiency of Paley's argument' (284).

design's inefficacy.[4] The anecdote was adopted in 1836 by William Josiah Irons, a High Church Anglican clergyman, theological writer, and lecturer at Oxford, and George Ensor, a distinguished Irish lawyer, author, and critic, who used it against the growing popularity of natural theology, pointing out that when the Bushmen look at the watch they do not see design. Irons and Ensor concluded that since seeing a watch does not produce conviction of design, the design analogy was logically faulty.[5] As Irons put it, 'man in examining Nature to find God is like a savage examining a watch—(let me add)—by Twilight!' (125).

Their critique did not go unanswered. William Whewell wondered in his Bridgewater Treatise how a savage could be expected to look at a steam engine and infer design and in his *Philosophy of the Inductive Sciences* he used Campbell's story as evidence that the 'Idea of Design' must be developed before a person looks at an object.[6] Baden Powell made a similar point, asking whether the Bushmen had the necessary rational skills, and suggesting that Paley 'never contemplated the reasoning as addressed to savages' (284). But where Irons and Ensor totally rejected the design analogy based on the Bushmen's responses, Whewell and Powell recognized the importance of the differing cultural, personal, and historical contexts of people who observe watches. As twentieth-century interpreters of these South African encounters suggest, 'none of the objects was introduced into a void, and while they brought novel values … they also acquired meanings different from those intended by their donors' (Comaroff and Comaroff 184).[7] Objects, like watches or steam engines, do not contain all their meanings within themselves, but those meanings are partly constructed by observers and their cultures. For Englishmen, watches had the meanings necessary for the design analogy to work. For the Bushmen, they did not. How? What were those meanings? What were the cultural paraphernalia that allowed a watch to mean design for a European but not for a Bushman? How were they created?

In tandem with and underpinning my discussions of natural theology, I will answer these questions by exploring specific meanings of machines, how they were created, and how they enabled design's plausibility with a British audience. Before engaging specific meanings, however, this chapter will outline my methodological approach to the meanings of machines. It will argue that these meanings were constructed discursively through a 'literature of technology', which the chapter introduces. Then it will explore the creation of

[4] Although translated earlier, D'Holbach's was important enough to retranslate and republish in 1820 by one Samuel Wilkinson.
[5] Irons 123-127; Ensor 17.
[6] *Astronomy* 350; *Philosophy* 2: 80-81
[7] Anthropologists, sociologists, and ethnographers call this 'recontextualization'—the change in a material object's meaning and value as it moves or is moved from one social context to another.

one meaning that machines needed for design to work: intelligibility. It will demonstrate how an emerging genre of 'popular technology', particularly expositions of the steam engine, constructed machines as comprehensible first through the simple expression of machines in books and then through the creation of a language for talking about them, activating the cultural assumption that explanation equalled knowledge. Finally, it will show how this model of mechanical intelligibility not only cognitively enabled perception of design by constituting human design as intelligible, but also internally shaped how the argument from design proceeded in the 1830s.

Meaning Things, Meaning Machines

In early nineteenth-century Britain, mechanical metaphors harnessed the fecund meanings of machines to do specific cultural work within natural theology. As discussed in chapter one, metaphors utilize the attributes of one thing to understand or express another. While some mechanical metaphors primarily exploit the concrete qualities of machines like their noisiness, greasiness, or metallic quality, the design analogy was based on an intangible attribute of machines: that their evident design indicated an intelligent designer. But design as an intuition also required a whole network of other abstract meanings to guarantee design's plausibility. The question, as suggested by Campbell's anecdote, is how machines acquired those intangible meanings essential for the design analogy's appeal. Engaging with established methods in studying the meanings of 'material culture', this section will outline my historicist approach to how machines became meaningful objects in cultural context in order to lay a foundation for answering this question.

The meanings of things fascinate scholars from a variety of disciplines. In archaeology, anthropology, and ethnography, 'material culture' has been a major portal for studying societies and cultures.[8] In the 1970s, material artefacts were taken as embodying the culture which produced them.[9] In the 1980s and 90s, scholars began to understand things as readable sign systems while recognizing that things relate to culture flexibly—embodying

[8] For essays on material culture from archaeological perspectives, see Hodder; from anthropological, see Appadurai; Buchli; and from ethnographical, see Daniel Miller. For a history of 'material culture studies', see Hicks.

[9] American historical archaeologists James Deetz and Henry Glassie were major proponents of this view: Deetz argued that material culture is 'not culture but its product' (35) and Glassie that 'material culture is culture made material' (qtd. in Stahl, 'Material' 153; Glassie 41). For a history of this view, see Stahl, 'Material' 153-154.

and reinforcing, but also diverting and challenging it.[10] Most recently, some social science scholars have begun to reject these 'logocentric' and 'culturalist' approaches because they reduce things to their ideational 'meaning', instead attending to the *material* of material culture, to the enactment of things rather than representation of them.[11] By contract, scholars within the humanities, among whom I place myself, tend to emphasize the *culture* in material culture. They maintain that material objects cannot be taken as givens because they do not precede language or theory, but are bound up in them.[12] Thus the relationship between matter and meaning is complex. Arguing that 'things are simultaneously material and meaningful' (17), historian Lorraine Daston identifies a paradox whose terms map onto different approaches to things in literary studies: 'the brute intransigence of matter' coupled with its 'plasticity of meaning' (16). In the 1960s to 80s, Marxist criticism focused on matter's 'brute intransigence' by emphasizing the material-industrial mode of production for determining meaning, while new historicism in the 1980s and 90s prioritized an object's 'plasticity of meaning' by reading an object alongside a seemingly incongruous literary text, illuminating how they participated in the same culture.[13] But from the end of the twentieth century, Bill Brown's 'thing theory' addressed the relationship of things and texts head-on by looking for the 'limit cases' where 'meaning and materiality' disintegrate.[14] Uninterested in the cultural meanings of specific things, thing theorists investigate the cultural attitudes toward 'things' and 'objects' as categories through time, which Brown finds worked out in literature by asking how objects are 'represented in this text? And how are they made to mean?' (*Sense* 18).

Yet where literary thing theorists and social scientists have begun to move away from 'what the culture meant objects to mean' (Plotz, 'Can' 110), many historians from a variety of humanities disciplines, including myself, still pursue that very project. They ask questions of a thing in order to access history—to understand a feature of a specific culture at a specific moment in time. With them, specific objects 'talk only because an enormous amount of

[10] Major texts in the linguistic turn within material culture studies include Ian Hodder's *Symbols in Action* (1982) and *Reading the Past* (1986), Christopher Tilley's *Metaphor and Material Culture* (1999), and the essays collected by Hodder in *The Meaning of Things: Material Culture and Symbolic Expression* (1989) and by Tilley in *Reading Material Culture: Structuralism, Hermeneutics, and Post-Structuralism* (1990). For the 'varying roles and functions which material culture may play within a particular culture or cultures' (Ucko xiii), see the essays collected in Hodder.

[11] For this 'material turn', see the essays in the *Oxford Handbook of Material Culture Studies* (2010) edited by Mary Beaudry and Dan Hicks. For a critique of logocentrism, see Stahl, 'Colonial' 827; and of 'culturalist' leanings, see Hicks and Beaudry 2. For enactment, see Hicks.

[12] Gadamer 77-78; B. Brown, 'Things' 1-3.

[13] Greenblatt 2150.

[14] See B. Brown, 'How', *Sense*, 'Thing'. On this reading of thing theory, see Plotz, 'Can' 110.

effort has been put into delineating the context, the interpretive community, in which such speech can be heard', according to Victorianist John Plotz ('Can' 110-111).[15]

Specific developments in nineteenth-century studies and in the history of technology also inform my approach to the meanings of machines in the 1830s. In studies of nineteenth-century British material culture, Asa Brigg's *Victorian Things* (1988) set the precedent by considering specific things in conjunction with 'an examination of the contemporary publicity surrounding things—much of it rhetorical' (16).[16] Subsequent cultural critics and historians have largely followed suit in what Lyn Pykett has called a twinned 'textualisation of history' and 'textualisation of things' (3), as they assume that things have cultural meanings constructed for them, not by them. In works on Victorian tea, shawls, diamonds, glass, and portable property, material objects are explored through the ways they are represented, in novels, advertisements, and non-fiction prose, rather than through their actual physical manifestations.[17] Instead, these scholars run the risk of fetishizing their material objects, taking tea as a category and shawls as a category, even as they explore the proliferation of their meanings. In general, these Victorian objects have been studied as commodities, but Elaine Freedgood, in *Ideas in Things* (2006), claims that a 'thing culture' preceded 'commodity culture'.[18] Interested in 'the knowledge that is stockpiled' (2) in and 'the fugitive meanings of apparently nonsymbolic objects' (4), Freedgood takes things in Realist novels of the 1840s—a mahogany table or plug of tobacco—not as symbols, but as literal representations of material things which had a 'radiance or resonance of meaning' (5-6) for readers. Like others, she finds those meanings in other texts. Thus while these projects often claim to be about *material* objects in the nineteenth century, they are really about their *cultural* manifestations.

The relationship between culture and material technologies specifically has interested many historians and philosophers of technology, who often ask how technology 'matters' and what it means.[19] Technological determinists claim that technology determines culture, while constructivists claim that social and cultural forces determine, or at least shape,

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[15] For examples of this 'culturalist object theory', see the essays in Daston, but especially Wise and Wise. For fieldwork alternatives, see the essays in Beaudry and Hicks, and for specific attacks on culturalist approaches, see Hicks.
[16] For overviews of material culture in Victorian studies, see Pykett; Sattaur.
[17] On tea, see Fromer. On shawls and diamonds, as well as tea and cotton, see S. Daly. On glass, see I. Armstrong; A. Miller. On portable property, see Plotz, *Portable*.
[18] On commodities, see S. Daly; A. Miller; Waters, *Commodity*.
[19] For MacKenzie and Wajcman, 'technology matters' because it shapes society (3), while for Nye 'technology matters because it is inseparable from being human' (ix). Additionally, Arnold Pacey has explored the 'meaning in technology', but has chosen to set aside the 'social' or 'public' meanings to pursue personal meanings gained through experience of technology.

technologies.[20] Today, most allow that society and technology mutually shape each other, but constructivists offer useful concepts for talking about the 'meaning' of technology. Trevor Pinch and Wiebe Bijker famously insist on the 'interpretive flexibility' of technology—that a technology means different things to different social groups and that the 'stabilization' of a new technology involves the closure of that flexibility.[21] But where they have been interested in the ways changing meanings of a technology shaped its physical construction, a few scholars within the humanities, whom I follow, have charted the changing public and abstract meanings of machines. From a historicist and textualist perspective, Jonathan Sawday has investigated how machines were imagined during the Renaissance, while Tamara Ketabgian has explored Victorian understandings of machinery and how they intertwined with conceptions of the human.[22]

My project absorbs many of the assumptions, principles, and methodologies of these theorists and historians. Working within the humanities, I take the plasticity of a thing's meaning to indicate that its meaning is not contained entirely in its materiality. Although granting that physical attributes impact meaning, I learn from Campbell's watch anecdote that an object's significance is culturally contingent. Like other students of nineteenth-century culture, I pursue the *cultural* meanings of machines, setting aside personal or linguistic significance and economic value. These meanings are cultural because they are shared understandings and significances functioning and circulating within the cognition of a certain set of people.[23] And although there are many ways those meanings could be created and circulated, I follow Freedgood by studying machines in the 1830s as pre-commodity 'things' with rich and proliferating meanings created by their representation—or construction—in texts.[24] Indeed, machines as physical objects do not appear in my work, but are always refracted through discourse. I explore the rhetorical and literary tools which made machines meaningful and culturally fruitful objects which provided cognitive and rhetorical

[20] Jacques Ellul famously talked about the 'autonomy' of technology, by which he meant that 'technology ultimately depends only on itself, it maps its own route' (125) and as such 'that technology radically modifies the objects to which it is applied while being scarcely modified in its own features' (126). For the 'Social Construction of Technological Systems' (SCOT) view, see Pinch. For foundational essays on the social shaping or construction of technology, see Bijker, Hughes, and Pinch; Mackenzie and Wajcman

[21] On 'interpretive flexibility', see Bijker.

[22] Historians Ben Marsden and Crosbie Smith have investigated rhetorical constructions of technological and professional systems woven by engineers which contributed to the social success or failure of those technologies.

[23] I take my rough definition of 'culture' from Clifford Geertz who understands it as 'the webs of significance' in which humans are 'suspended' (5), as consisting of 'socially established structures of meaning' (12). I do, nonetheless, recognize the embattled state of Geertz's conception, see the essays collected in Ortner.

[24] A thing's significance varies in 'density' (Weiner qtd. in Myers 9), 'promiscuity' (Nicholas Saunders 176-177), 'eloquence' (Daston, 'Introduction' 15), or 'thickness' (Gallagher and Greenblatt 25), not just in content. See also, Daniel Miller 'Why'.

resources for many ways of thinking in the 1830s, but particularly for natural theology. For the second quarter of the nineteenth century was, after all, the great age of print as much as it was the great age of steam.

Tracking *what* machines meant, I also explore *how* they meant. Although I am claiming to exhaust neither the significances of machines nor the paths to that significance, I will explore one cluster of ways machines became meaningful: a tripartite grouping of literary and linguistic forms. First, a literature of technology translated machines from physical into cultural objects by creating a language about them and then by constructing specific meanings for them. Second, mechanical metaphors transferred those meanings from one cultural field into another—into religious discourse, political economy, or poetics. And third, natural theology was a site of the impact of those meanings, of the cultural work they did. What holds this cluster together is its discursivity: the machine's meanings were created by discourse, transferred by metaphor from one discourse to another, and then did work in that new discourse.

The Generic Meaning of Machines

The 'machine' was an important conceptual category for early nineteenth-century Britons, about which they thought, spoke, and wrote. Rich discourses sprang up around this keyword and its synonyms, simultaneously exploring and constructing meanings of 'machine' that went beyond its specific lexical denotations to build its cultural connotations.[25] Machines were talked about in parliament, visually depicted in prints and plans, discussed in periodicals from the *Westminster Review* to the *Mechanic's Magazine*, debated in pamphlets, and more thoroughly treated in books. Each of these media contributed to the meanings of machines, but I focus on an emergent 'literature of technology' which was newly enabled by early nineteenth-century advances in steam-printing technology. Comprising multiple sub-genres, including popular exposition, industrial travel narrative, mechanics textbook, and history of inventions, the 'literature of technology' constructed meanings of machines both through its explicit content and through its generic forms—through the 'genre-level meaning' (Liddle 154) each variety evoked.

Putting 'literature' and 'technology' into positive relationship instead of lining them up as archenemies goes against the grain of many assumptions in the humanities, which often

[25] Those synonyms included '*mechanic* (or *useful* or *practical* or *industrial*) *arts*, or *invention*, *improvement*, *machine*, *machinery*, or *mechanism*' (Marx, 'Technology' 563).

see themselves as defending the human from the technological.[26] Traditionally, scholars of nineteenth-century literature have been particularly prone to this stance: in 2000, Herbert Sussman diagnosed such a 'technophobic pedagogy' plaguing the teaching of Victorian literature ('Machine' 197). Influenced by a Romantic tradition inherited from William Wordsworth, Matthew Arnold, and Raymond Williams, scholars of Victorian literature have instinctively recoiled from the technologies of the nineteenth century, a repulsion magnified by the human toll of industrialization.[27] They have often either passed over the technological context with a token comment about the great social changes precipitated by the Industrial Revolution or they have interpretively magnified the critique of technology offered by industrial novels like Disraeli's *Sybil* (1845) or Gaskell's *North and South* (1855). Amplified by Marxist approaches, the opposition between literature and technology has recently been reinforced by ecocriticism, which makes technology even more deeply abhorrent as the Industrial Revolution shoulders much blame for humanity's alienation from nature and for today's ecological crises. Yet some positive scholarly formulations of the relationship between 'technology' and 'literature' have begun to emerge, even within the normally technophobic studies of the nineteenth century. In 1992, a collection of essays edited by Mark Greenberg and Lance Schachterle staked out the study of 'literature and technology' as an 'emerging focal area within technology studies' (Cutcliffe and Goldman 12). But it took a decade for literary scholars to bring their own expertise on 'literature' to this new domain. Enabled by the growth and success of 'literature and science' studies and a 'turn to technology' in science and technology studies in the 1980s, a number of literary scholars have begun to explore the varied and varying relationships of literature and technology through time.[28]

An early comer to this field, Tim Armstrong identified a number of possible 'linkages' between technology and literature. Indicating ways their relationship has been approached in literary scholarship, Armstrong lists 'literature *on* (about) technology; literature *in* (produced or influenced by) technology; even literature *as* (a mode of) technology' ('Introduction' 121).[29] The earliest, clearly demarcated area to emerge, scholars first investigated attitudes toward technology overtly articulated in literature, then moved on

[26] Wylie Sypher, an American Guggenheim fellow, claimed in 1968 that 'the artist's vocation is resistance to human engineering' (250), to the view that 'all can be calculated, formulated, regulated' (250).
[27] For a brief history of the opposition between culture and industry, see Bizup 1-17, who goes on to offer a historical exploration of how culture and industry were understood as intertwined in the 1830s and 1840s.
[28] A few continue to consider 'literature and technology' through the frame of science, see Marchitello; M. Turner.
[29] T. Armstrong first took up the topic in 1998 with *Modernism, Technology and the Body: A Cultural Study*.

to studying how technology has been 'imagined'—how it has been represented and constructed through literature.[30] Seeing literature and technology as emerging from the same cultural ground, these scholars study machines as rich cultural signifiers with complex meanings at a single moment as well as with changing meanings over time.[31] Interest in the influence of technology on literature has been a significantly more diffuse approach, including Marxist and technological determinist privileging of production or technology in determining cultural products. Indeed, soft technological determinism permeates much scholarship as technological turning points, the printing press or the military technologies of the Great War, also become major literary turning points which register emergent cultural hegemonies.[32] More concretely, many scholars, following Walter Ong and Elizabeth Eisenstein, have studied how literature has been materially produced by technology—by the actual, physical technologies of printing and reading.[33] In nineteenth-century studies, the technologies of book production and media technologies have become major topics, important because they identify the roots of today's media culture.[34] Finally, literature itself has been understood as a technology: language is a communication technology while literature is a tool for manipulating the world or for expressing thoughts or feelings.[35]

The contrast between these three approaches indicates the complexity of literature's relationship to technology, inviting deeper and more focused investigation. But while they differ, recent scholars also share a foundational assumption: that the relationship between literature and technology changes over time. Although often filtered through a desire to understand the now, this scholarship collectively rejects ahistorical theories about the relationship between technology and literature. Instead, in keeping with the British tradition of studying the relationship between literature and science, these projects insistently apply Fredric Jameson's injunction to 'always historicize!' (9) to studying the relationship between

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[30] For studies of overt attitudes toward technology, see Sussman, *Victorians*; the less sophisticated Roshwald. For studies of imagining technology, see Coleman and Fraser, 'Introduction' 4; Freeman 19; Goody 1; Kang; Ketabgian 4; L. Marx, *Machine* 4; Sawday xv. The focus on 'imaginative history' was largely established by Humphrey Jennings's 1985 *Pandaemonium* (xxxv), a collection of excerpts on machines from the eighteenth through the twentieth centuries.

[31] As part of the same cultural matrix, see T. Armstrong, *Logic*. As cultural signifiers, particularly symbols and metaphors, see Ketabgian 1; L. Marx, *Machine* 4; Sawday 68. As changing over time, see Bizup; Kang; Pettit, *Patent*. Such studies are often organized around key topics: the human, (Ketabgian), the body (T. Armstrong, *Modernism*), techniques of representation (Broglio; Grossman; Menke).

[32] This is especially true of Modernism, see T. Armstrong, *Modernism*; N. Daly; Goody.

[33] Ong postulated the 'technologizing of the word' during the shift from oral to writing cultures while Eisenstein traced the emergence of 'print culture' with the advent of the printing press.

[34] On book production, particularly the impact of steam-printing, see Fyfe, *Science, Steam*. On media technologies, see Colligan and Linley; Kittler 177-372; Menke; Otis

[35] On language as a technology, see Jackson; Plato 274-275. On literature as a technology, see Siskin. A text can also work like a machine, see Otto; M. Turner.

technology and literature.[36] Because neither 'literature' nor 'technology' is static, their relationship cannot be static.[37]

Joining this emerging field of 'literature and technology' studies, I take up this historicism, but I also hope to explore new territory, guided by the contiguous field of 'literature and science' studies. One of this neighbour's most valuable tools has been close attention to the literariness of science—to the linguistic and literary forms which express, record, and constitute science. For the nineteenth century, this has meant a focus on the 'literature of science': on Lyell's *Principles of Geology* or Darwin's *Origin of Species* or the incredible boom in popular science publishing in the early century. This approach needs to be assimilated more obviously into the study of 'literature and technology', to add a 'literature *of* technology' to Armstrong's *on*, *in*, and *as* linkages. Many of the best studies have implicitly turned to literatures of technology in order to explore the relationships between technology and other cultural formations.[38] In the 1960s and 70s philosophers and historians of technology recovered some of these texts, making them available in re-prints and facsimile editions, many published by Frank Cass in its Library of Industrial Classics. More recently, Elaine Freedgood has collected 'industrial writing' about the factory system in an easily teachable collection, *Factory Production in Nineteenth-Century Britain* (2003). But while the most prominent of these texts have been made available and then utilized by scholars seeking to reconstruct the 'technological imaginary', they have not been the explicit focus of sustained study. My project remedies this neglect by surveying and partially theorizing the early nineteenth-century literature of technology as a set of texts, asking how people wrote about technology and why it mattered.

Building on genre theory, I approach the literature of technology by arguing that the literary forms used to package or represent machines did much of the work in constructing their meanings. I pay attention to two such literary forms: genre and metaphor. Generally, the project progresses by looking at the way various genres within the 'literature of

[36] On early modern literature and technology, see Marchitello; Sawday; Wolfe. On nineteenth-century, see Bizup (1830s-50s); Broglio (1750-1830); the essays collected in Coleman and Fraser, *Minds* (1770-1930); Grossman (1836-57); Ketabgian (1830s-70s); L. Marx, *Machine* (1840s-1900); Menke (1840s-1900); Sussman, *Victorians* (Victorian); Sypher (late Victorian); Pettit, *Patent* (1818-1900); Tresch (1820s); M. Turner, *Mechanism* (late eighteenth to early twentieth centuries). On Modernism and modernity, see N. Daly (1860-2000); Goody (1890s-2000); T. Armstrong, *Modernism* (1890s-1950s).

[37] On changing meanings of 'Literature' between 1700 and 1830, see Siskin.

[38] For the nineteenth century, Bizup's *Manufacturing Culture* explores how 'an identifiable proindustrial rhetoric' (4) constructed nineteenth-century machines as part of culture, Ketabgian's *The Lives of Machines* puts 'industrial accounts' (17-18) next to literary texts to show how conceptions of machines shaped conceptions of human-ness and emotional affect and vice-versa, and Pettit's *Patent Inventions* suggests through textual comparison that engineers and authors shared conceptions of intellectual property.

technology' constructed meanings of machines that were then captured and put to work within religious discourse by another literary form—metaphor. Before proceeding to discuss the literature of technology, however, I want to recognize that metaphor, which I usually consider after genre in each chapter, is not just a conduit for meaning but also produces meanings for machines in its own right. Metaphor has been a major starting place in relating literature and science since the ground-breaking work of Gillian Beer in *Darwin's Plots* (1983). I have borrowed this attitude in studying 'literature and technology', for metaphors do significant cultural work: they 'serve as subtle epistemological, conceptual, and cultural tools that are imbued with a wide range of cognitive, emotional, and ideological connotations'.[39] In the nineteenth century, they harnessed the meanings of machines to serve apologetic and religious ends through natural theology's design analogy. But this harnessing also did work on machines. While metaphors project qualities from the base to the target, there is also a reverse movement in which both terms interact and are changed. In this backwash of significance, elements are 'recruited to the source under pressure from the target' (Turner and Fauconnier 405). Most simply, metaphors applied to machines made them into a coherent category which was generalizable and thus culturally ubiquitous. They aligned the fecund and sometimes contradictory meanings of machines by organizing them within a structure partly shaped by the target onto which they were projected. Finally, mechanical metaphors endorsed the cultural assumption that technology was a good and beneficial thing by showing that God made machines also, inherently theorizing technology and invention.

If metaphors, as a discursive form, constructed meanings of machines, then the genres of writing about technology also constructed those meanings, providing even more specific and concrete significance. In many ways, the study of genre has been more welcome outside literary studies than within it.[40] Following a Romantic tradition refracted through M.H. Abrams, literary scholars often avoid genres because they seem either to be ill-fitting prescriptions or to be formulas on which inferior writers depend but which great ones transcend.[41] Yet over the twentieth century, there has been a limited recovery of the concept

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[39] Nünning, Grabes, and Baumbach xii. See also Semino 22; Ricoeur, *Rule* 93; Eubanks 437.

[40] Recent work within the history of science has paid close attention to the generic forms of science writing, for example, see Lightman, *Victorian*; O'Connor, *Earth*.

[41] This 'anti-generic hypothesis' (Duff, *Romanticism* 1) about Romanticism was established by M.H. Abrams, who emphasized the 'expressive' literary theories of Romantic poets and other writers, and associated a rejection of genre with the Romantic celebration of originality and individual genius. Duff, on the other hand, overturns this view to show that ideas about genre were inseparable from Romanticism. On genre as a 'law', see Derrida, 'Law'

of genre for literary study, beginning with a rejection of the Aristotelian and neo-classical conception of 'genre' as taxonomic prescription. [42] Instead of stable, timeless entities, genres are now considered flexible, ubiquitous, performative, dynamic, ramifying, historically-contingent, and necessary for—even constitutive of—communication.[43] Genres do not form an abstract, completed taxonomy classified according to form and content, but 'a set of conventional and highly organised constraints on the production and interpretation of meaning' (Frow, *Genre* 10) and they are 'temporary structures … that *last* in time, but always only for *some* time' (Moretti, *Graphs* 14). Two basic approaches to genre have emerged (and sometimes merged): a sociological and morphological.[44] The second attends to how genres have changed, developed, ramified, and reified over time. The first attends to what genres do, to the functions they have performed.

Whether favouring the morphological or sociological, modern genre theorists have continually insisted that genre is not a prescriptive restraint, but a generative construct which transmits and enables meaning, both for writers and readers. Genre is identified as a carrier of meaning by a huge number of thinkers about genre: Fowler suggests that 'genre is an instrument not of classification or prescription, but of meaning' (22) while Hirsch claims that 'all understanding of verbal meaning is necessarily genre-bound' (76).[45] More deeply still, genres are 'of a piece' (Moretti, *Signs* 6) with worldview or ideology for famous thinkers like Bakhtin, Jameson, and Moretti.[46] Largely synthesizing the work of his predecessors, John Frow argues in *Genre* (2006) that the 'structuring effects' of genre 'are productive of meaning' (10) for 'generic structure both enables and restricts meaning, and is a basic condition for meaning to take place' (10). But he goes further to argue that genres 'actively generate and shape knowledge of the world' (2) through their 'formal organisation, … rhetorical structure, and the thematic content' (4). So despite recent historicist practice which

[42] For an introduction to modern genre theory, on which my own approach is based, see Frow, *Genre*. For an introductory collection of foundational writings in modern genre theory, see Duff, *Modern*.
[43] Frow introduces many of these qualities of genres in *Genre* 1-3. On ubiquity, he says that every text is 'shaped and organized by its relation to generic structures' (1-2). On performativity, he says that texts 'use' rather than 'belong' to genres (2-3, see also 25-28). He also calls them 'open-ended' (28) and 'historical and processual' (71). On their flexibility, dynamism, and ramification, see Fowler 149-212; Frow, '"Reproducibles"'.
[44] For sociological theories, see Jameson; Moretti, *Signs*; Todorov. A combination of morphological and sociological can be found in Moretti, *Graphs*.
[45] See also Frow, *Genre* 10; Jameson 113-114; McLuhan 7; Opacki 119.
[46] Bakhtin, 'Discourse' 289, 311; Jameson 141; Moretti, *Signs* 6.

emphasizes meanings created primarily by readers, the public *how* of the meaning is as important as its private and individual *what*.[47]

Genre theorists would suggest that the what and the how of a text's meanings are not distinct. Neither readers nor writers make up the meanings they put into or get from texts: those meanings are partly constituted by the genre a writer selects or a reader perceives a text to be, as Bakhtin and Jauss agree.[48] At the level of writing, genres are 'performative structures that shape the world in the very process of putting it into speech' (Frow, '"Reproducibles"' 1633).[49] But they are equally powerful at the level of reading and interpretation, a point that has many observers, including Bakhtin, Hirsch, Jameson, and Jauss. E.D. Hirsch, in a work foundational to modern genre theory, suggested that 'the details of meaning that an interpreter understands are powerfully determined and constituted by his meaning expectations' (72), which are themselves encoded in his 'generic expectations' (73). Hirsch goes on to claim that 'all understanding of verbal meaning is necessarily genre-bound' (76). Corroboratively, reception theorist Jauss provides this idea's most codified statement and handle. He argues that readers receive and interpret a work through a 'horizon of expectations', through the genre they think it is. Finally, Jameson elaborates: readers understand texts through 'the sedimented reading habits and categories developed by … inherited interpretive traditions' (9). In summary, what a text means to readers is largely determined by the genre in which they pre-locate it, as readers have a 'horizon of expectations' about what that genre is, does, and means.

Informing my work, Dallas Liddle has transferred these insights into the study of nineteenth-century literature in *The Dynamics of Genre: Journalism and the Practice of Literature in Mid-Victorian Britain* (2009). Using Bakhtin's theories to posit 'genre-level meaning' (154), Liddle suggests that for many texts, all a reader needs to know is their genre in order to understand their meaning. Tracing the influence of journalism and its genres on poets, novelists, and prose writers as well as the conflict between those genres in the middle decades of the nineteenth century, Liddle has called for a 'map of Victorian genres' (73). But his is not a simple literary history, for genres 'come preloaded with deep reserves of meaning' (154). To trace genres and their uses and reuses, then, is to trace the development and interaction of worldviews and meaning systems. For, according to Jameson, even when a genre is 'reappropriated and refashioned' in a new context, 'the ideology of the form itself …

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[47] For applied studies that emphasize the particular meanings of texts for particular readers, see Rose; Topham, 'Beyond'.
[48] See Bakhtin, 'Problem' 79; Jauss 143.
[49] For the power of genre for writers, see Rosmarin.

persists into the later, more complex structure as a generic message which coexists—either as a contradiction or, on the other hand as a mediatory and harmonizing mechanism—with elements from later stages' (141).

Seeking to expand Liddle's 'map of Victorian genres', my project will chart the synchronic topography of genres deployed within the 'literature of technology'. Instead of following genres and their mixings and intermixings through time, it will trace the specific shapes these genres took in a specific moment, while acknowledging the instability, flexibility, and provisional nature of that system. Although providing a rough descriptive sketch of some of the genres deployed within the literature of technology, it will not attempt to establish a complete taxonomy (of the classical variety) nor, in terms of modern genre theory, either a diachronic account of the morphology of genres or a synchronic account of the way they relate to other genres. While it offers a brief history of the genres and their trajectories within the literature of technology, it is most interested in what these genres did to the meanings of machines—in the meanings these genres carried and imparted. Although contributing to literary history, this project is really about the work those genres did as carriers and creators of meaning. It humbly follows in the path of Mary Poovey's *Genres of the Credit Economy* (2008) which proceeds upon the idea that genres, as 'representational systems' within certain types of writing from literary writing to paper money, made ideas and content 'socially usable' (12).

Learning from a wide variety of theorists and critics, then, I study the literature of technology's forms by putting them in historical context and asking what they meant to readers and writers at a specific moment in time. As Jauss suggests: 'the reconstruction of the horizon of expectations, in the face of which a work was created and received in the past, enables one … to pose questions that the text gave an answer to, and thereby to discover how the contemporary reader could have viewed and understood the work' (28). Part of this project attempts this kind of 'reconstruction', tracking the genres used to represent machines, what meanings those genres carried with them and then imparted to machines, and what wider questions these generic meanings answered.

Making Machines Mean: The Literature of Technology and its Genres

During the first few decades of the nineteenth century, machines became the explicit subject matter of a group of texts which I call the 'literature of technology'.[50] This literature materialized to deal with the new technologies of the Industrial Revolution and the new cultural formations associated with them, like factories, the working class, and political radicalism. According to Freedgood, one of their few students, these texts 'helped to write into existence a [factory] "system" that was still taking shape through the middle of the nineteenth century' for they 'created and constructed a social reality for their readers as much as they represented or tried to reflect a reality that was already in existence' (*Factory* 3). This literature assumed two basic modes with widely varying histories: the technical and the popular. While the technical had a long and distinguished history in the 'machine books' of the Renaissance, its popular counterpart emerged in the early 1820s, in response to multiple cultural shifts.[51] With the end of the Napoleonic wars and the fading of foreign threats, British attention was refocused on domestic issues, precipitating a redefinition of the nation in terms of the arts of peace instead of the arts of war.[52] Enabled by the development of a popular reading audience and joining new popular science writing directed at that audience, 'popular technology' described new technologies and their inventors, justifying the importance of industry to Britain.[53] Emergent in a period (1818-1837) that Victorianist Alan Rauch complains is 'often neglected, ignored, or tacitly considered "post-Romantic" or "Pre-Victorian"' (*Useful* 7), these texts have suffered much the same fate, neglected and ignored by most. Recovering and interpreting these texts begins with acknowledging that this was not just a transitional period between Romanticism and Victorianism, but what Rudwick has studied as the 'Age of Reform' lasting roughly from 1820 to 1840 (*Worlds*).[54] Although my project does not deal with reform directly, it recognizes a specific milieu lasting roughly from

[50] Today, this type of writing is often called 'technology writing'. The University of Michigan Press even published an annual *Best of Technology Writing* compendium (2006-2008), which migrated to Yale University Press under the name *The Best Technology Writing* (2009-2010). Looking at the past, scholars in the history of engineering have begun to think about the literatures of technology, as evidenced in a recent workshop entitled 'Literary Engineering' held at the University of Aberdeen on 17 March 2010, involving Casper Anderson, Ben Marsden, Mike Chrimes, Graeme Gooday, Christine MacLeod, Frances Robertson, Don Legget, Ralph O'Connor, and Klaus Staubermann. Yet the bibliography of published works on this topic is fairly small, including Freedgood's introduction to her collection and A. P. Woolrich's several articles on John Farey's technical writing.
[51] On Renaissance 'machine books', see Sawday 70-124.
[52] On this refocusing, see MacLeod *Heroes*.
[53] On the emergence of 'popular science' in the 1820s and 1830s, see Topham, 'Publishing'.
[54] Many historians have identified an 'age of reform', but they usually let it stretch from the 1780s to 1832 or from 1832 to the late nineteenth century. On the history of the phrase, see Innes and Burns 1.

1820 to 1840 that made a battle over the machine's meaning not only possible but important as people struggled to understand—and control—the great mechanical prime movers of their time.

Similar to popular science, 'popular technology' consisted of texts, lectures, and sites in which knowledge about the workings and development of machines, factories, steam engines, and railways, was presented and consumed.[55] I focus on texts because the printing of books about technology had special meaning for the cultural significance of machines through the discourses it created.[56] Whether considering the historical, technical, practical, sociological, political, or commercial, these texts focus on the machine, considering it as a system or fitting it into larger physical, scientific, or economic systems. Freedgood has begun the work of surveying what she calls the 'literature of industrialization' (9) in *Factory Production in Nineteenth-Century Britain*, arguing that 'industrial development in Britain generated new genres along with new modes of production and that each of these new genres reflects a mode of understanding, and often of critiquing, the nascent system it confronts' (x). She identifies several genres: literary critique, industrial novel, '"condition of the labouring population" books', the 'book of factory abuses', 'the factory tourist tale', 'histories of particular industries', and 'autobiography' (9-16). But where Freedgood asks about the factory, I ask about the much broader category of the 'machine'. Taking a narrower timeframe than Freedgood's, my argument centres on four genres of the 'literature of technology' between 1820 and 1840: popular expositions of steam engines, industrial travel narratives, mechanics textbooks, and histories of invention. Yet it also recognizes and incorporates other genres, like dictionary or encyclopaedia entries and biography or autobiography, and other modes, like industrial protest or the industrial sublime.[57] While this project considers the literature of technology as a context for understanding the power of natural theology, I hope that its introduction of the history and taxonomy of 'popular technology' will encourage and serve as a foundation for future consideration of the literature of technology.

Although textual treatments of technology emerged much earlier, they began to be directed toward the public for informational, rather than practical or commercial, reasons in

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[55] A current example of this genre would be the Hearst Corporation's American monthly magazine *Popular Mechanics*.

[56] On lectures and sites in which machines were popularly communicated or consumed, see Morus, *Frankenstein's,* 'Manufacturing', 'Worlds'. On the 'sites' of popular science, see the essays collected in Fyfe and Lightman.

[57] Following Fowler, Frow sees modes 'as the extensions of certain genres beyond specific and time-bound formal structures to a broader specification of "tone"' (65).

the second half of the eighteenth century. In that century's drive toward unified knowledge, dictionaries and encyclopaedias included entries on the 'arts' like printing, textile manufacturing, and mining, and even some entries on the steam engine.[58] But as knowledge differentiated in the early nineteenth century, works concerned solely and directly with technology and machines appeared, fishing technology out of the soup of general knowledge.[59] Some of these were technical works—treatises, manuals, journals, and textbooks—written for people who actually worked on or with technology. Instead of being an entirely new form, however, this was an old one borrowed from the sciences. Indeed, this treatise form gave birth to mechanics textbooks in the 1820s and 1830s, including William Whewell's *An Elementary Treatise on Mechanics* (1819) and Henry Moseley's *A Treatise of Mechanics* (1834), a set of scientific and mathematical texts directed at well-educated men, rather than at engineers or technologists.

Beyond these technical and professional works, however, there were a plethora of texts written for non-professional and popular readers. Two major forerunners of 'popular technology' help found a conceptual framework for recognizing its early nineteenth-century forms. In 1817, Johann Beckmann's *A History of Inventions and Discoveries* was republished in English, giving brief histories and descriptions of various material arts.[60] Within a decade, English histories of various inventions, processes, and products were published. These works, like Richard Guest's *A Compendious History of the Cotton Manufacture* (1823) or Elijah Galloway's *History of the Steam Engine from its First Invention to the Present Time* (1826), nested descriptions of physical technologies within histories of their inventions. The other early text, the Marquis of Worcester's *A New Century of Inventions* (1655) detailing one hundred of his own inventions, was the forerunner of expositions of technology, also appearing from the 1820s onwards. These expositions took on a variety of topics at variable levels of specificity. Some were surveys of the best new technological inventions from a variety of industries and pursuits, like James White's *A New Century of Inventions* (1822) or George Drysdale Dempsey's *The Machinery of the Nineteenth Century* (1852). The invention that drew the most interest—and was the subject

[58] The titles of these works hint at their polymathic quality: John Harris's *Lexicon Technicum: Or, An Universal English Dictionary of Arts and Sciences* (1704); Ephraim Chambers's *Cyclopaedia: Or, An Universal Dictionary of Arts and Sciences: Containing the Definitions of the Terms, and Accounts of the Things Signify'd Thereby, in the Several Arts, both Liberal and Mechanical, and the Several Sciences, Human and Divine* (1728); John Barrow's *Dictionarium Polygraphicum: Or, the Whole Body of Arts Regularly Digested* (1735); [John Barrow]'s *A New and Universal Dictionary of Arts and Sciences* (1751); and Abraham Rees's *Cyclopaediea: Or, Universal Dictionary of Arts, Sciences, and Literature* (1802-1819).
[59] On the differentiation of practical from abstract knowledge, see C. Fox; Stewart.
[60] The German title, published 1780-1805, was *Beiträge zur Geschichte der Erfindungen*.

of the most exposition—was the steam engine, explained in works like Dionysius Lardner's *Popular Lectures on the Steam Engine* (1828) or Hugo Reid's *The Steam-Engine: Being a Popular Description of the Construction and Action of that Engine* (1838). The most fascinating of the steam engine's applications, steam transport whether by rail or by sea, drew significant attention, as in John Gilbert's *The Railways of England: Containing an Account of their Origin, Progress, and Present State* (1839). Others focused on the steam engine's manufacturing applications, relating the material technologies to commodities, processes, and products, as in Richard Guest's *The British Cotton Manufactures* (1828) or P. Barlow's *A Treatise on the Manufactures and Machinery of Great Britain* (1836). In a specific vein, industrial travel narratives also explained factory mechanisms and their relations, as in George Dodd's *Days at the Factories* (1843), but nested them within a geographical narrative of discovery.

These textbooks, expositions, histories, and travel narratives assumed that machines were valuable and beneficial, but not everyone agreed. With Lord Shaftesbury's campaign to regulate factory labour, especially for children, a new topically-defined genre emerged: texts dealing with the 'factory question'.[61] Producing works both pro- and anti-machine, the factory question asked whether material machines were beneficial to the individual, community, and state. On the anti-manufacturing side were works like Peter Gaskell's *The Manufacturing Population of England* (1833) and John Fielden's *The Curse of the Factory System* (1836), while on the pro-machinery side were such industrial classics as Charles Babbage's *On the Economy of Machinery and Manufactures* (1832) and Andrew Ure's *The Philosophy of Manufactures* (1835).[62] I include the anti-machine texts as part of popular technology because they explain the physical and social functioning of factories as compound machines and describe the relationship of machines to people and society.

This general mix of texts continued into the 1830s and 40s, often with subsequent editions and expansions of late 1820s texts to incorporate railway technology. But in the 1840s and 50s, other genres emerged and ascended, marking the end of the moment I am studying. The Chartist agitations of the 1840s made factories, mechanics, and the industrial classes even more fraught topics. The 'Condition-of-England Question' identified by Thomas Carlyle in *Chartism* (1839) precipitated the highly-critical industrial novels of the 1840s and 50s, including Benjamin Disraeli's *Sybil, or The Two Nations* (1845), Elizabeth Gaskell's *Mary Barton* (1848), Charles Kingsley's *Alton Locke* (1849), and Charles

[61] Standard accounts of the factory question can be found in Berg; Gray.
[62] See Bizup for a systematic consideration of pro-machinery responses to the factory question.

Dickens's *Hard Times* (1854).[63] Although literary scholars implicitly lionize these authors for their critiques of industrialism, Freedgood has pointed out how little difference they made: there was 'no threat that they [would] be considered as policy initiatives in the real world. The anti-industrialism of Victorian "literary" works did not threaten the spread of the factory system; rather, it provided a helpful site of harmless critique' (*Factory* 9). As the crises of the 1840s gave way to the smug stability of the 50s and 60s, other sites and genres for representing machines became popular. The Great Exhibition at the Crystal Palace in 1851 created its own set of texts, often guides to the mechanical exhibits in the Exhibition. Later in that decade, the literature of technology turned toward Plutarchian life-writing focused on the inventors of technology, headed by Samuel Smiles' *Life of George Stephenson* (1857) and *Lives of the Engineers* (1862). Later in the century, the focus swung back from the inventors to the machines themselves and texts about machinery often became children's prize books.[64]

This brief history has introduced the 'popular technology' subdivision of the literature of technology, yet this title is as problematic as naming a 'popular science', difficulties framed in terms of its definition, how it distributed or created knowledge, and its audience.[65] In definition, both 'popular' and 'technology' are problematic. 'Technology' is an anachronism: it was used rarely in the early nineteenth century and when it was used, it denoted a different meaning to ours. Coined in the mid-sixteenth century, 'technology' originally signified a body of knowledge and its language, like biology or geology, rather than material objects. Instead, the nineteenth century talked about 'machinery' or the 'machine' to refer to physicalities.[66] But that term eventually failed as a useful conceptual category around 1900, to be replaced by 'technology' for talking about material things.[67] Even so, it did not achieve widespread popular use until the 1930s.[68]

Beyond historical anachronism, 'technology' is problematic for other reasons. Technology is, according to David Nye, 'an unusually slippery term' (*Technology* 15). Not only historically variable, it is also invested with a huge range of meanings by contemporary philosophers and critics. Carl Mitcham, a philosopher of technology and engineering, notices

[63] Carlyle, 'Chartism' 151.
[64] For an account of this shift, see MacLeod, *Heroes* 371-382.
[65] On the problematic nature of 'popular science'—and a defense of using the concept, see Lightman, *Victorian* 9-13.
[66] Harvard professor Jacob Bigelow did try to popularize 'technology' in a set of lectures in America published as *Elements of Technology* (1829), succeeding with a few Brits, including Andrew Ure (*Philosophy* viii, 13)
[67] On this failure and replacement, see L. Marx, 'Technology'.
[68] For histories of the word 'technology' and its referents in the US and Germany, see L. Marx, 'Technology'; Nye, *Technology* 7-15; Schatzberg.

that it 'is not a universal term; it does not mean exactly the same thing in all contexts' (152). He goes on to list a number of contrasting philosophical definitions: technology is applied science for Mario Bunge, 'rational efficient action' for Jacques Ellul, the 'pursuit of power' for Lewis Mumford, knowledge of technique for Nathan Rosenberg, and 'control of the environment to meet human needs' for Stanley Carpenter (153). Mitcham concludes, however, that technology should be 'described as the making and using of artifacts' (153). While the philosophers he summarizes tend to define technology as something abstract and superstructural, Mitcham's material significance is closest to the popular meaning of technology today, in which it is understood through its referents—the internet, computers, iPads. Mitcham manages to link the popular and philosophical definitions together by suggesting that with all uses of the term 'there is a primacy of reference to the making of material artifacts, especially since this making has been modified and influenced by modern science' (152).

Anachronism, imprecision, and ambiguity are not the only problems with the term. Also noticing the primacy of the material reference, Leo Marx warns that 'technology' is actually a dangerous concept. He argues that 'consigning technology to the realm of things' endows technology with 'a thing-like autonomy and seemingly magical power of historical agency' (577). This reification of technology 'distracts attention from the human-socioeconomic and political relations which largely determine who uses them and for what purposes' (576). People can thus throw up their hands and blame technology for the problems of the modern world without taking responsibility themselves.

Yet using such a problematic term has benefits as well. First, it signals that my work participates in the disciplinary projects of the history of technology. Second, as a 'retrospective analytical concept' (*Industrial* 2) 'technology' allows us to move beyond the limitations of historically-situated language to trace the development of concepts or phenomena which had not yet been named because they remained below a certain threshold of conceptualization. The anachronistic, reified concept of 'technology' will thus serve as a constant against which to measure the materialization and stabilization of the 'machine' as a body or object of knowledge in the early nineteenth century. Looking at the meaning of 'machine' in our cluster of texts, we can trace the developing perception of machines as comprehensible through the hardening and honing of the term into something very similar to today's popular connotation of 'technology' as a newly-invented material object for doing some kind of work. Thus negotiating between the 'logos' denotation of technology and its material denotation, this chapter is about the development of technology as a body of knowledge, but will use the word 'technology' to mean material objects and processes, because it is most consistent with today's usage. And, finally, using the popular, material denotation of the term allows me to gesture towards a continuity between today's technoculture and early nineteenth-century technoculture. It verbally signals that the cultural move I am discussing—the construction of meanings for technology by words and texts—happens today as it did in the 1830s.

'Popular' is also a problem, one which has been thoroughly treated by historians of popular science.[69] This adjective suggests certain power and knowledge structures which did not necessarily function or exist: it assumes a diffusionist model of the spread of knowledge in which experts pour their knowledge into the passive, empty heads of novices.[70] Instead, scholars, like Jonathan Topham, have emphasized the agency of publishers, printers, readers, and reviewers in creating the meaning of popular science texts.[71] In some ways, I sidestep the question of a public for popular technology by suggesting that the genre constructed the machine as knowable to a public, rather than suggesting that the genre actually made the machine known to that public. But more directly, because the sources of much mechanical knowledge were non-scientific engineers and mechanics, popular technology had a different structure of knowledge and power than popular science. The 'popular science' which nineteenth-century historical actors recognized involved a science heavily complicit with class structure, identifying the man of science as both a social and financial gentleman.[72] The scientific knowledge presented to popular audiences was tightly regulated by the middle, educated classes—by Henry Brougham and George Birkbeck who oversaw the popularization of science through the Society for the Diffusion of Useful Knowledge and lectures at Mechanics' Institutes.[73] But the 'expert' on popular technology was not a genteel man of science but a newly-minted 'engineer', shifting the class implications of the genre. In historical terms, he (and always he) was a technical and practical man, with rough hands and a grimy face. While inventing engineers like James Watt were sometimes re-branded as gentlemen by the scientific and political elite, the everyday expert on the machine was the

[69] Lightman, *Victorian* 13-17; Topham, 'Publishing'.
[70] Bernard Lightman outlines the various models of scientific popularization held by critics. The first is the 'positivist diffusion model' which dominated scholarship into the 1990s while the remaining three 'share the goal of recovering the agency of groups who participated in the making of science for the general audience' in the nineteenth century. They 2) draw attention to marginalized groups and sciences, 3) focus on publishing, and 4) stress various sites where science for general audiences was found (*Victorian* 14-17). For examples of the last three approaches, see the essays in Fyfe and Lightman; Topham, 'Beyond'.
[71] Topham, 'Beyond'.
[72] For 'popular science' as a phrase used by nineteenth-century actors, see Lightman, *Victorian* 11. For class implications in the development of science, see Morrell and Thackray; Shapin, *Social*.
[73] Shapin and Barnes.

hands-on artisan who used the machines every day or the machine-maker, variously called a mechanic, mechanist, or mechanician. Even so, 'popular technology' was not recognized as a category distinct from 'popular science' by these historical actors: its texts were circulated through the publishing and communication circuits of popular science while a number of its writers, about the steam engine for example, were professional popular science writers.

Despite their absorption into the communications circuit of popular science, popular technology texts had a distinguishable structure of power and knowledge, a different construction of the relationship between producer and consumer in the production of knowledge about machines. The question of who has knowledge, has access to it, and makes it was particularly open with technology where it was more limited with science. Developing into a profession, mechanical engineering had permeable boundaries open to any man willing to learn, often through experience, how machines worked and how to design them.[74] Directed sometimes at working men, popular technology augmented experiential knowledge of machines, giving them further information that could allow them to raise themselves as the many engineers of the nineteenth century had done. Thus, through popular technology, a working man could become the expert: the consumer of popular technology could become the producer of popular technology. In this sense, then, popular technology was truly popular, if by popular is meant egalitarian, with the possibility that anyone could contribute to or consume this knowledge. So these texts are 'popular' not because of a certain structure of that expert-novice relationship or of the expert-public relationship, but because they constructed the machine as accessibly knowable to everyone, not just experts, professionals, or scientists.

In a wider view, this openness of knowledge and the blurring of boundaries of expertise begins to break down the distinction I drew earlier between popular and technical texts. The permeability of mechanical knowledge and expertise, as well as the relative narrowness of this knowledge, meant that what would otherwise be popular texts could easily turn into practical primers for ambitious young men hoping to break into the profession. At the same time, seemingly 'technical' or 'practical' treatises could become popular, if by popular is meant widely-read and disseminated. The extent to which many working and middle class men turned to mechanics and manufacturing for their livelihoods suggests that any text about technology or engineering could become popular in this period because of the

[74] The openness of early nineteenth-century engineering is evidenced by the huge influx of 'engineers' and engineering hopefuls during the railway mania of the 1840s. For a history of engineering as a profession, especially its emergence as a profession over this period, see Buchanan.

nature of the topic. Indeed, many works were written to those with a rudimentary, but not highly technical, knowledge of machines from working as artisans. By differentiating popular technology from popular science, we see how fully the machine was presented as comprehensible to the 'public' both through the diffusionist communication of knowledge about it, but also through the implication that even men who were not scientific experts could produce knowledge about machines. Overall, popular technology as a genre destabilized the expert-public knowledge structure, also destabilizing the distinction between popular and practical/technical texts. Thus popular technology offered the machine as a knowledge object to the public in such a way that made that knowledge egalitarian and open to all interested in pursuing it. Mechanical knowledge was not exclusive, but public and popular: anyone and everyone could understand the machine.

Despite complications, then, I will continue to refer to a 'popular technology' within the 'literature of technology' because the phrase offers a frame through which to view the dual development of a 'literature' and the knowledge it carried or constructed. Foundationally, 'popular technology' is useful because it frames the emergence of machines as a general topic for books that anyone, not just engineers, could read. Additionally, looking at 'popular technology' breaks down the division between literature on the one hand and factories, machines, and technologies on the other. Isolating popular technology allows us to see that there is no simple antagonism between technology and literature; they are both part of the nineteenth-century definition of the arts as the application of learning, knowledge, or skill. Indeed, Hugo Reid could claim in1828 that the steam engine was second only to printing as the most important invention in history (*Steam* v-vi). And, shifting from the object to the inventor, Robert Stuart could claim in 1829 that mechanical invention was as valuable a pursuit as literary invention. He went further, claiming that 'all poets are mechanical inventors, and all mechanical inventors are poets' (*Historical* 1: xxv-xxvi).[75]

Mysterious Machines: The Industrial Sublime

Campbell's African anecdote with which this chapter began suggests that the meanings of machines are not inherent in machines, but provided by the minds and cultures of their observers. Working out the implications of the anecdote, this chapter has so far explored the meaningfulness of technology theoretically and how the cultural meanings of

[75] Although she does not quote Stuart, Pettit considers how discussions of literary copyright and inventive intellectual property borrowed from each other, highlighting the kinship of authors and inventors (*Patent*).

machines were constructed by a popular literature of technology during the 'Age of Reform'. But Campbell's anecdote also has more to say about the meanings of machines. First, absorbed by critics of natural theology in the 1830s, the story indicates why the meanings of machines were important: they were necessary for the functioning of natural theology's design argument. Second, the story identifies a specific meaning of machines required by the design analogy: for an object to appear designed, it had to be understandable and explainable, rather than a mysterious and supernaturalized object of wonder. Because the Bushmen did not understand how the watch worked, they saw it as the product of magic rather than of design. The human mind's ability to trace cause-and-effect in nature is thus essential to natural theology, in contrast to the theologies of nature which recognize something supernatural in effects without tracing them to material causes. Although Paley claimed that even the 'unmechanical looker-on' will perceive design if he perceives purpose (43), his argument really depends on the idea that once the mechanism is '*observed and understood*, the inference, we think, is inevitable; that the watch must have had a maker' (8, emphasis added). To perceive design is to perceive an object as understandable and explainable—as intelligible because it is not the product of magic. Campbell's vignette thus wrong-foots much recent scholarship on natural theology's logic and rhetoric which links design to purpose rather than to intelligibility. Instead, while purpose and benefit are important to the logic of design, the story suggests that the comprehensibility of artefacts and of nature is essential to the cognitive functioning of natural theology.

That human contrivances, like watches or steam engines, are comprehensible seems almost self-evident today. But there was a point in time when this meaning for machines was constructed against competing discourses in which machines were magical and mysterious. The Bushmen's fearful and wondering response to the watch was a reportedly consistent pattern in African confrontations with European technologies.[76] Even the autobiographical *The Interesting Narrative of the Life of Olaudah Equiano* (1792) mentions Equiano's surprise at seeing a working clock for the first time and his fear that it was an animated object that 'would tell the gentlemen any thing I might do amiss' (44). But it was not just Africans who failed to understand machines or to recognize their intelligibility.[77] Englishmen cultivated a surprisingly similar, although not identical attitude, through what has been called the 'technological sublime'. It grew out of Edmund Burke's conception of the

[76] On African responses to European technologies, especially clocks, as animate, see Comaroff and Comaroff 191-192.
[77] A highlander in Sir Walter Scott's *Waverley* (1814) thought a watch 'which he took for a living animal' had died when it stopped ticking (229).

sublime as productive of awe and terror through an object or view being 'dark, uncertain, confused' (Burke 36-37, 55).[78] In the Burkean sublime, the 'obscure' and inexplicable qualities of the object provoke an emotional rather than rational response from the viewer.[79] Indeed, according to Burke 'it is one thing to make an idea clear, and another to make it *affecting* to the imagination' (55).

Both literary and visual works responded to technology in this mode. Applied to machines, it trained observers to view machines as wonderful, inscrutable, and obscure, rather than clear and explainable. Visually, Phillip James de Loutherbourg's 1801 *Coalbrookdale by Night* (Fig. 2.1) presents the billowing smoke and flashing fire of the Bedlam Furnace, but hides the workings of the furnace behind the buildings in the middle distance, making it a mysterious and terrifying object. His interest is not in how the furnace works, but in the exaggerated scene's affect.[80] Textually, a letter Thomas Carlyle wrote from Birmingham to his brother John in 1824 reads as an excellent caption for de Loutherbourg's scene:

> torrents of thick smoke, with ever and anon a burst of dingy flame, are issuing from a thousand funnels. 'A thousand hammers fall by turns.' You hear the clank of innumerable steam-engines, the rumbling of cars and vans, and the hum of men interrupted by the sharper rattle of some canal-boat loading or disloading…. I have seen their rolling-mills, their polishing of teapots, and buttons, and gun-barrels, and fire-shovels, and swords, and all manner of toys and tackle. I have looked into their iron works where 150,000 men are smelting the metal in a district a few miles to the north; … and the whole is not without its attractions, as well as repulsions. (qtd. in Froude 231-232)

As a discourse, mode, and affect, the technological sublime depends on the mystery and obscurity of technology to produce the emotions of terror and wonder. In it, observers wonder rather than inspect and understand. Although not intentionally contradicting the comprehensibility of machines, the technological sublime precludes it by encouraging the viewer not to lift the metaphorical bonnet, but just enjoy the adrenaline surge in listening to a finely-tuned engine. This mode was reinforced by public lectures and mechanical museums

[78] The 'technological sublime' was first recognized and named in the 1960s by P. Miller 295-306; L. Marx, *Machine* 214, 195-207, 230-231; Sussman, *Victorians* 29. Nye summarizes the concept and its sources, both critical and historical, in introducing *American Technological Sublime*, building his broad-ranging history around this concept (xv-xx).

[79] Burke 54-55.

[80] On the picturesque, related to the sublime, in visual representations of industrial scenes and its contrast with accuracy, see C. Fox 362-444.

Fig. 2.1. Phillip James de Loutherbourg, *Coalbrookdale by Night*, London Science Museum, United Kingdom.

like London's Adelaide Gallery and Royal Polytechnic Institution where machines were presented in terms of 'the marvellous and the spectacular', invoking experience of their physical power and spectacle.[81]

Surprisingly, this public obscurity and opacity of machines was cultivated by mechanics, engineers, mechanicians, manufacturers, and mill-wrights because secrecy was essential to their professional livelihoods.[82] At the individual level, inventors carefully guarded the principles and structures of new inventions before a patent had been won, in order to protect their investments and guarantee their future profits. And once the patent had been granted a degree of secrecy was maintained to avoid the lawsuits involved in prosecuting for patent infringement. At a national level, manufacturers and engineers feared industrial espionage from foreigners who, if they could understand the mechanism and then draw well enough, could carry the idea back to their own countries and begin to make the machine without fear of legal consequences.[83] These spy operations could be elaborate

[81] Morus, 'Manufacturing' 420, 417-426.

[82] This secrecy was supported by the material conditions of nineteenth-century Britain. Machines and manufacturing were often isolated to the industrial north while their presence in the metropolis was hidden by the orderly exterior of factories.

[83] Harris.

affairs, including disguises, assumed names, and careful timing.[84] When Birmingham hosted the eighth meeting of the British Association for the Advancement of Science in 1839, few manufacturers opened their mills to the curious attendees. Indeed, James Watt, Jr., chafing at the suggestion that manufacturers were obliged to open their mills, wrote in an *Athenaeum* article:

> The sooner we resume our ancient habits of privacy and exclusion, particularly with regard to such progresses which we may still alone possess, the more it will tend to the advantage of our manufacturing interests. And narrow minded as these opinions may appear to the members of the British Association and to some of our political economists, we hope that our warning voice may not be raised in vain, to prevent a repetition of such suicidal folly. (qtd. in Morrell and Thackray 264)

In practice, however, Watt, Jr., had little to fear from the general, domestic visitor, for the technological sublime served as a shield for mechanical knowledge.

The secrecy of mechanical knowledge was also safeguarded by the extraordinary difficulty and technicality of language in patents, which was often unintelligible to the general public. This raised the problem of an adequate language for communicating mechanical knowledge. Demonstrations on the popular science lecturing circuit sidestepped this problem in a way which increased both the wonder and the secrecy of technology. They depended on mechanical apparatuses and instruments which the lecturer sought to make as invisible as possible to heighten the wonder of his experiments.[85] While machines were there, attention was insistently shifted from their workings to their products, rendering them unseen. This secrecy and its attendant (and widespread) technological ignorance combined with the technological sublime to foster an attitude in which machines were wonderful and powerful, but were unintelligible and therefore might have been the product of magic as easily as of design.

Reading and Writing Machines: The Steam Engine

The sublime was not the only lens for perceiving machines in the early nineteenth century. An alternative mode also emerged which saw machines as intelligible rather than mysterious. The new popular literature of technology helped create and disseminate the

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[84] C. Fox 378.
[85] For an account of the 'invisible technician' in science lecturing, see Shapin, 'Invisible'.

perception that man-made artefacts were knowable to anyone and everyone by making them the objects of explicit, verbalized knowledge. For a culture where explanation equalled knowledge, these texts catalysed the perception that machines could be explained and therefore known. I am not concerned with who actually knew about technology, what they knew, or whether it was accurate, but with how machines became perceived as publicly comprehensible and about the discourses and texts that created this perception.

A first step in the construction of machines as widely intelligible was their packaging in books. Working out the implications of Marshall McLuhan's famous dictum that 'the medium is the message', this claim is predicated on the idea that specific forms have specific meanings in historical contexts. The packaging of machines in physical books as opposed to lectures, in words as opposed to visual images, carried a specific message to early nineteenth-century consumers. In a re-writing of McLuhan, Leah Price has tested the possibility of treating the 'container as content' (253), asking 'what meanings do books make even, or especially, when they go unread?' (2). Revising Price, what meanings did books make about machines? Broadly, books were associated with knowledge, truth, and power, for engrained in Western culture is a 'link between print and veracity'.[86] In the Christian world, books have been powerful symbols of status, intellectual sophistication, and authority.[87] Indeed, cultures of knowledge emerged with print cultures, reflecting the link between books and knowledge. This link was particularly important in the early Victorian mindset. Books and access to books represented knowledge and access to knowledge. Mechanics' Institutes, Working Man's Libraries, and series like the Society for the Diffusion of Useful Knowledge's Library of Useful Knowledge offered people knowledge by offering them books. In this context, putting machines into books represented machines as comprehensible—not through the denotative meanings of the books or the words, but through the connotations of the book-as-medium. Whether or not books actually explained machines effectively, the implication that books communicate and explain rubs off on the object discussed in them, constructing machines as intelligible.

Not only was the book a symbol of knowledge, but the act of reading was a metaphor for the act of understanding.[88] This metaphor is rooted in a Christian tradition which identifies divine and natural revelation as the 'two books' through which people can know about God. From the middle ages through the mid-nineteenth century, natural philosophers

[86] Johns 638.
[87] Manguel 214, 217. The authority of the book is particularly high in Christian cultures because they are centered, especially in Protestantism, around knowing God through a collection of sixty-six books—the Bible.
[88] Manguel 163-173.

defended their vocations by claiming that they were reading the book of nature to gain knowledge of God. To read was to understand. When machines emerged in books, they too could be 'read', playing into the established metaphor for understanding. Overall, then, popular technology sought to explain machines to the general reader. But before a person even opened a book to read about machines, the aura of intelligibility carried by the book and by the act of reading constructed the machine as intelligible, whether or not a person bought, read, or understood the book.[89] Widespread awareness that books about machines existed built a foundation for a public perception of machines as comprehensible.

Judging a book by its cover, the external medium of popular technology formulated machines as comprehensible, but so did the words between the boards. In the 1820s and 30s, a subset of popular technology emerged which was specifically concerned with technological explanation: expositions of the steam engine. These dozen or so texts (Table 2.1) constructed machines as intelligible not merely because they actively explained machines, but because of *how* they explained them. Perceived comprehensibility first requires that something be formulated as an object of knowledge. Things become objects of knowledge when they are 'articulated', when they go through 'the process through which tacit skills and knowledge are made explicit' (Håkanson 51-52).[90] Texts about the steam engine 'articulated' mechanical knowledge: they formulated machines as comprehensible objects of knowledge by creating and disseminating a language through which they could be discussed. This new language was not for the people who already had tacit knowledge about machines—mechanics, engineers, millwrights—but for the general public, enabling discussion about machines in the 'public sphere'.[91] Although informed by sociological studies of knowledge, especially in my understanding of knowledge as tacit/explicit and private/public, mine is not a sociology of technical knowledge, but a consideration of how machines were conceptualized and presented as a subject of explicit and public knowledge.[92] I am not concerned with whether machines were *actually* the objects of public knowledge nor about the development of the

[89] Of course, books could be published and not purchased, purchased and not read.
[90] In 1967, Michael Polanyi's *The Tacit Dimension* (1967) shifted scholarship on knowledge toward tacit (informal or physical '"know-how"') as opposed to explicit knowledge (MacKenzie 11). Emphasis has started to swing back toward explicit knowledge, see Håkanson. On the philosophical question of whether explanation equals understanding in science, see the essays in *Studies in History and Philosophy of Science* 44 (2013): 505-538.
[91] For the introduction of the concept of the 'public sphere', see Habermas. For critiques, see the essays collected in Calhoun; Warner 65-124, who offers a new definition of publics according to the media which create them. For historicist applications of this concept to science in the early nineteenth century, see Golinski, *Science*; Yeo, *Defining* 24-48.
[92] These dichotomies permeate sociological studies of knowledge, but were mediated to me by MacKenzie's *Knowing Machines* (11, 221).

content of mechanical knowledge. Instead, I am concerned with the perception that they were intelligible and with the cultural significance of the translation of machines into language. Concerned with words, with discourse, with what expression in language meant and accomplished, mine is a literary approach to mechanical knowledge.

Books were not the only place where the public encountered machines. Historian of science Iwan Rhys Morus explores some of these alternative sites and provides an alternative methodology to mine. Where I am concerned with words, Morus is concerned with actual places in which people experienced machines.[93] In the 1830s, the Adelaide Gallery and Royal Polytechnic Institution, with which I began my introduction, allowed Londoners to come into contact with machines. Scientific demonstrations were a large draw to these venues, which offered intertwined edification and entertainment.[94] Such demonstrations often involved complex and sophisticated 'technologies of display' (Morus, '"More"' 339). But explicit knowledge of machines was not the purpose of the performances. Instead these spectacles sought to awe the audience, inviting them to figure out how the lecturer had achieved certain effects and thus to recognize his ingenuity and mechanical 'virtuosity', but to inquire no further (362-364). Such London establishments were preceded by exhibitions at Mechanics' Institutes in northern industrial cities. These exhibitions collected industrial technologies, among other things, for observation, providing visual experience but few demonstrations.[95] Lectures, however, were the most significant component of the educational projects of Mechanics' Institutes. But, rather surprisingly, these lectures focused more on pure than on applied science, failing to address contemporary technoculture.[96] Together the London galleries and the exhibitions at northern Mechanics' Institutes created public spaces for experiencing machines, but those experiences remained largely below the threshold of overt conceptualization. They thus presented machines as the objects of wonder and of tacit, experiential knowledge. Books, by contrast, translated machines into language, making them the objects of rational, explicit knowledge.

A public language for talking about and understanding machines was fabricated and disseminated by expositions of the steam engine in the 1820s. Generally, these popular texts comprise two elements: a history of the engine's development plus a description of its components and operation. They begin with a historical narrative describing the development of the parts of the steam engine within a teleological framework selecting only

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[93] For a collection of essays emphasizing the 'sites' and 'experiences' of science, see Fyfe and Lightman.
[94] Morus, '"More"' 348.
[95] Kusamitsu 34-36.
[96] Roderick and Stephens 29.

the innovations contributing to Watt's engines. When they arrive at Watt, they abandon historical narrative to describe in detail the components, operations, and innovations of Watt's single- and double-acting steam engines. The texts thus understood themselves as expositions of contemporary, tangible machines, for the engine had changed little in the thirty years the double-acting engine had been in use. Depending on diagrams, they illustrate and describe the primary parts of the engine and how they relate to each other. They then explain the functioning of the engine—from the creation of steam right through to the force exerted at the application point. Perhaps their best description was provided by Dionysius Lardner in his *Popular Lectures on the Steam Engine* (1828):

> A simple and clear explanation divested as far as possible of technicalities, and assisted by well-selected diagrams, is all that is necessary to render the principles of the construction and operation of the Steam-Engine intelligible to a person of plain understanding and moderate information. (v-vi)

Where de Loutherbourg's technological sublime had kept the machine in an obscure middle distance, these texts took the reader right inside the machine to see every cog and wheel clearly and thus to understand how the parts fit together.[97] Lardner's confidence that the machine was 'intelligible' became a self-fulfilling prophecy as the language of these works put machines into language and thus positioned them as public knowledge.[98]

Mechanical knowledge long pre-dated the entry of machines into texts like these, but it was often tacit and un-verbalized, implicitly private and limited. During the eighteenth-century 'industrial enlightenment', mechanical knowledge was transferred either through personal interaction or through the circulation of people with tacit mechanical knowledge, precluding communication from one person to another.[99] Bolton and Watt, for example, seldom explained their products in writing.[100] But even during this period, lectures and encyclopaedia entries began to make mechanical knowledge explicit. Early verbalizations of machines in lectures, like J. T. Desaguliers's published in *A Course of Experimental*

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[97] Yet it is also a rather abstract perspective: there is no actual physical position from which a physical viewer could see all parts at the same time. The descriptions also abstract machines from their physical environments; these machines are not presented in any physical, social, or commercial landscape. There are no people, no products, and no factories.

[98] For the importance of 'intelligibility' as a criterion of acceptance for scientific theories, see Dear, 'Intelligibility', *Intelligibility*.

[99] Both knowledge and technology transfer are of current interest to historians of science and to economic historians. For example, the 2011conference of the European Society for the History of Science was entitled 'The Circulation of Science and Technology'. On the circulation of tacit knowledge through the movement of people, see Jones, *Industrial*.

[100] On Bolton and Watt, see Jones, 'Living'. Nevertheless, they did try to directly shape public views on industrialism, especially in the West Midlands, see Malcom.

	Table 2.1: Monographs on the Steam Engine, 1820-1840	
Date	**Author**	**Title**
1822	Charles Frederick Partington	*An Historical and Descriptive Account of the Steam Engine*
1824	Robert Stuart	*A Descriptive History of the Steam Engine*
1825	James Cleland	*Historical Account of the Steam Engine and its Application in Propelling Vessels*
1826	Elijah Galloway	*History of the Steam Engine, from its First Invention to the Present Time*
1827	John Farey	*A Treatise on the Steam Engine: Historical, Practical and Descriptive*
1827	Thomas Tredgold	*The Steam Engine: Comprising an Account of its Invention and Progressive Improvement*
1827	George Birkbeck	*The Steam Engine Theoretically and Practically Displayed*
1828	Dionysius Lardner	*Popular Lectures on the Steam Engine: in which its Construction and Operation are Familiarly Explained; with an Historical Sketch of its Invention and Progressive Improvement*
1829	Robert Stuart	*Historical and Descriptive Anecdotes of Steam Engines*
1838	Hugo Reid	*The Steam-Engine: Being a Popular Description of the Construction and Action of that Engine; with a Sketch of its History, and of the Laws of Heat and Pneumatics*

Philosophy (1734) and James Ferguson's published in *Lectures on Select Subjects in Mechanics, Hydrostatics, Pneumatics, Optics and Astronomy* (1760), subsumed machines into expositions of Newtonian mechanical science.[101] The first expository works on the steam engine in a text-only medium intended for general audiences were John Robison's essays 'On Steam' and 'On Steam Machinery' for the *Encyclopaedia Britannica* between 1798 and 1803 and John Farey's 'Steam-Engine' in Rees's *Cyclopaedia* in 1816. But the expense and technical difficulty of such works made them accessible only to the wealthy and highly-educated, limiting the public intelligibility of machines.

Its opening up began slowly in the first decades of the nineteenth century. Part of the expansion of education, Mechanics' Institutes offered mechanical knowledge to working men by carrying on the lecturing tradition, building on the precedent built by Desaguliers and Ferguson. Yet while they did verbalize machines, lectures were, as Fyfe and Lightman have observed, still 'sites and experiences' in which the physical and spatial played an important role in the circulation of knowledge.[102] Lectures were often demonstrations rather than speeches, depending on the physical and visual presence of mechanisms and reactions to

[101] Ferguson's work remained popular and was republished in the nineteenth century, edited by David Brewster (1805) and C. F. Partington (1825).
[102] See Fyfe and Lightman 'Science'. The essays in Fyfe and Lightman, *Science*, are clustered around this point, but especially helpful is Lightman, 'Lecturing'.

them.[103] Opening knowledge and education to broader publics, these lectures linked words to physical machines and did produce the first texts on the steam engine offered to the public, including mechanics and artisans: Charles Frederick Partington's *An Historical and Descriptive Account of the Steam Engine* (1822), Robert Stuart's *A Descriptive History of the Steam Engine* (1824), and Elijah Galloway's *History of the Steam Engine, from its First Invention to the Present* (1826).[104] Thus the circulation of mechanical knowledge shifted from being accomplished by the physical movement of men with tacit knowledge, to lectures that verbalized machines but still depended on the physical, and finally to fully verbal textual expression in books. Generally, the possibility of popular access implies that a knowledge set has solidified through language so that what was once tacit knowledge had become explicit knowledge. The encapsulation of machines in words and books implies that they had been constructed as accessible to all.

These three early texts remained extremely tentative about how they would communicate and whether that communication would be successful, revealing that the transition from tacit and physical to explicit and verbal was incomplete. Partington offered his text to people with pre-existing knowledge of machines, 'the man of science and practical artisan', but he timidly hoped that 'every class of persons' would find it interesting—and understandable (*Historical* v). Galloway dedicated his to mechanics but tentatively offered it to 'the public' (vii). Stuart had the most confidence, directing his to mechanics and general readers alike (*Descriptive*). But with the newness of machines in words, each author depended on another epistemological source to legitimate his textual exposition of machines, to legitimate the truth and reliability of *words* about machines. Partington and Stuart drew on the dual physical-verbal structure of lectures for their legitimating strategy. Partington assumed that the reader has physical experience of machines in his explanations while Stuart depended on diagrams, attaching words as supplement rather than central vehicle. Although both use words, they obviously relied on the physical and visual to legitimate those words. Galloway, on the other hand, depended on a textual source of legitimacy: patents. He placed mechanical knowledge within an already-established structure of institutional power and knowledge. Altogether, they legitimate textual knowledge transfer by building on other, more established, means of acquiring or transferring knowledge: physical experience, diagrams, and technical specifications.

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[103] Morus has gone so far as to characterize such lectures as performances which made bodily affect central to their power ('Worlds').
[104] Partington's work cost 16s while Stuart's cost only 8s (C. Fox 551).

The possibility of expressing machines in words developed in multiple directions in the late 1820s and 1830s. In 1827, two practical and technical treatises on the steam engine written for engineers and mechanicians were published: John Farey's *A Treatise on the Steam Engine: Historical, Practical and Descriptive* and Thomas Tredgold's *The Steam Engine: Comprising an Account of Its Invention and Progressive Improvement.* While Farey's work has been celebrated as one of 'the finest monographs on technology published during the Industrial Revolution' (von Tunzelmann 2), Tredgold's became the standard work, going through multiple editions with additional appendices well into the 1860s.[105] By 1830, the success of this direction was evident in Luke Hebert's re-publication of Galloway's less technical work with a highly technical appendix, written by Hebert, about the applications of the steam engine.

At the same time, confidence increased in the popular appeal of the steam engine across a range of readerships beyond the working class or practical man. In 1828, Dionysius Lardner published his *Popular Lectures on the Steam Engine*, directed at the general reader of any class and entirely dependent on text, rather than physical experience or diagrams, although incorporating both. Lardner's work became the standard popular work on the steam engine, going through seven editions by 1840, with four more in the subsequent decades, multiple American editions, and translations into French, German, Italian, and Danish.[106] By 1876, his adumbrated *Rudimentary Treatise on the Steam Engine* had gone through thirteen editions in 28 years. The expansion of a general readership interested in the steam engine encouraged Partington to re-package his earlier work as *A Popular and Descriptive Account of the Steam Engine* (1836) while Stuart re-wrote his for a popular audience, titling it *Historical and Descriptive Anecdotes of Steam-Engines and of their Inventors and Improvers* (1829). There were also other new works on the steam engine, like Hugo Reid's *The Steam-Engine: Being a Popular Description of the Construction and Action of that Engine* (1838).

The increasing confidence both in public interest and in the possibility of expressing mechanical knowledge in words was reflected in a shift from a focus on history in Partington, Stuart, and Galloway to a focus on explaining the engine itself from 1829 onwards. This confidence is evident in the new—and exultant—opening Lardner added to the seventh edition of his work in 1840:

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[105] While Tredgold's was the most popular at the time, Farey's has drawn the only focused critical attention given to any of these texts, see Woolrich.
[106] Lardner's work was re-titled *The Steam Engine Familiarly Explained and Illustrated* for the sixth edition in 1836 and entirely re-written for the seventh edition in 1840. On its publication history, see Hays.

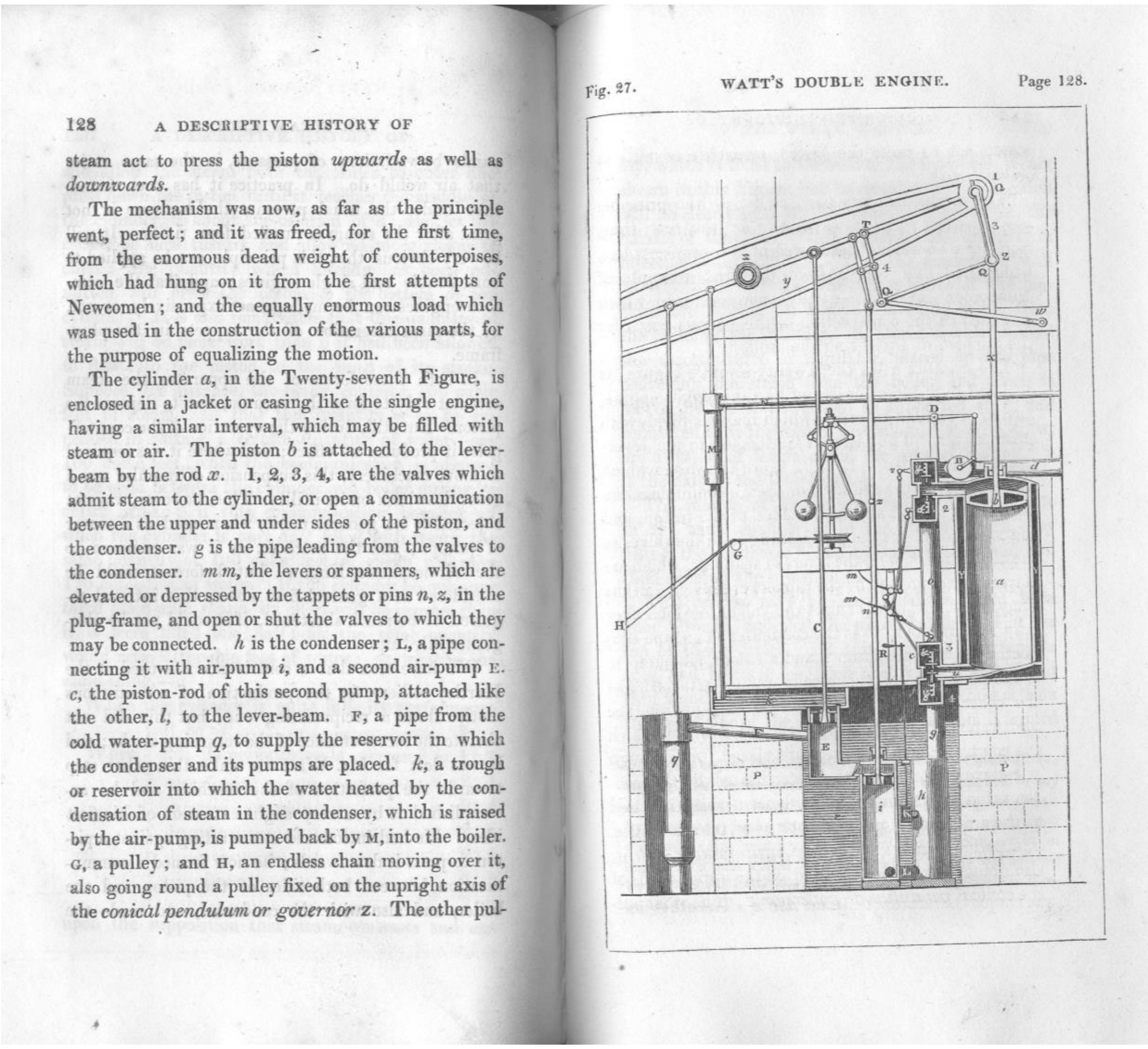
> That the history of the invention of a piece of mechanism, and the description of its structure, operation, and uses, should be capable of being rendered the subject matter of a volume, destined not alone for the instruction of engineers or machinists, but for the information and amusement of the public in general, is a statement which at no very remote period would have been deemed extravagant and incredible.
>
> Advanced as we are in the art of rendering knowledge popular, and cultivated as the public taste is in the appreciation of the expedients by which science ministers to the uses of life, there is still perhaps but one machine of which such a proposition can be truly predicated: it is needless to say that that machine is the Steam Engine. (*Steam* 3-4)

Through verbalization and textualization, mechanical knowledge had actually become popular knowledge, according to Lardner. So what happened in the eighteen years between the tentativeness of Partington, Stuart, and Galloway and the triumphant confidence of Lardner? How was his confidence both in the genre and public knowledge made possible?

Lardner's predecessors established the possibility of texts about the steam engine by carefully constructing a historical tradition of writing about them. The first three writers (Partington, Stuart, and Galloway) presented their books in terms of two textual traditions: first, general histories and second, descriptions by inventors of projected steam engines. They framed explanations of machines within historical narratives of their invention, using the growing legitimacy of history to structure technology, an as yet un-reified concept and phenomena. By turning it into a historical object, these authors ennobled the steam engine, making it an acceptable object of study. In the 1820s and 30s, these histories connected machines with national prosperity, making them rhetorically powerful.[107] Later writers, like Lardner, could lessen the historical structure because the machine had already been legitimated as an object of study in itself, with future rather than just historical value.

Consistent with contemporary historiographical methods, they used books to trace this history. Carefully noting how the development of the steam engine and of its attendant knowledge set was recorded in books, each discusses the writings of Hero of Alexandria, the Marquis of Worcester's *A Century of Inventions* (1659), and Thomas Savery's *The Miner's Friend; or, An Engine to Raise Water by Fire* (1702), which describe engines they either designed or planned to build. Instead of industrial archaeologists, nineteenth-century authors

[107] On their connection with national prosperity, see MacLeod, *Heroes*.



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steam act to press the piston *upwards* as well as *downwards*.

The mechanism was now, as far as the principle went, perfect; and it was freed, for the first time, from the enormous dead weight of counterpoises, which had hung on it from the first attempts of Newcomen; and the equally enormous load which was used in the construction of the various parts, for the purpose of equalizing the motion.

The cylinder *a*, in the Twenty-seventh Figure, is enclosed in a jacket or casing like the single engine, having a similar interval, which may be filled with steam or air. The piston *b* is attached to the lever-beam by the rod *x*. 1, 2, 3, 4, are the valves which admit steam to the cylinder, or open a communication between the upper and under sides of the piston, and the condenser. *g* is the pipe leading from the valves to the condenser. *m m*, the levers or spanners, which are elevated or depressed by the tappets or pins *n*, *z*, in the plug-frame, and open or shut the valves to which they may be connected. *h* is the condenser; L, a pipe connecting it with air-pump *i*, and a second air-pump E. *c*, the piston-rod of this second pump, attached like the other, *l*, to the lever-beam. F, a pipe from the cold water-pump *q*, to supply the reservoir in which the condenser and its pumps are placed. *k*, a trough or reservoir into which the water heated by the condensation of steam in the condenser, which is raised by the air-pump, is pumped back by M, into the boiler. G, a pulley; and H, an endless chain moving over it, also going round a pulley fixed on the upright axis of the *conical pendulum or governor* Z. The other pul-

Fig. 2.2. ‘Watt’s Double Engine’ and accompanying text from Robert Stuart’s *Descriptive History* (127-128).

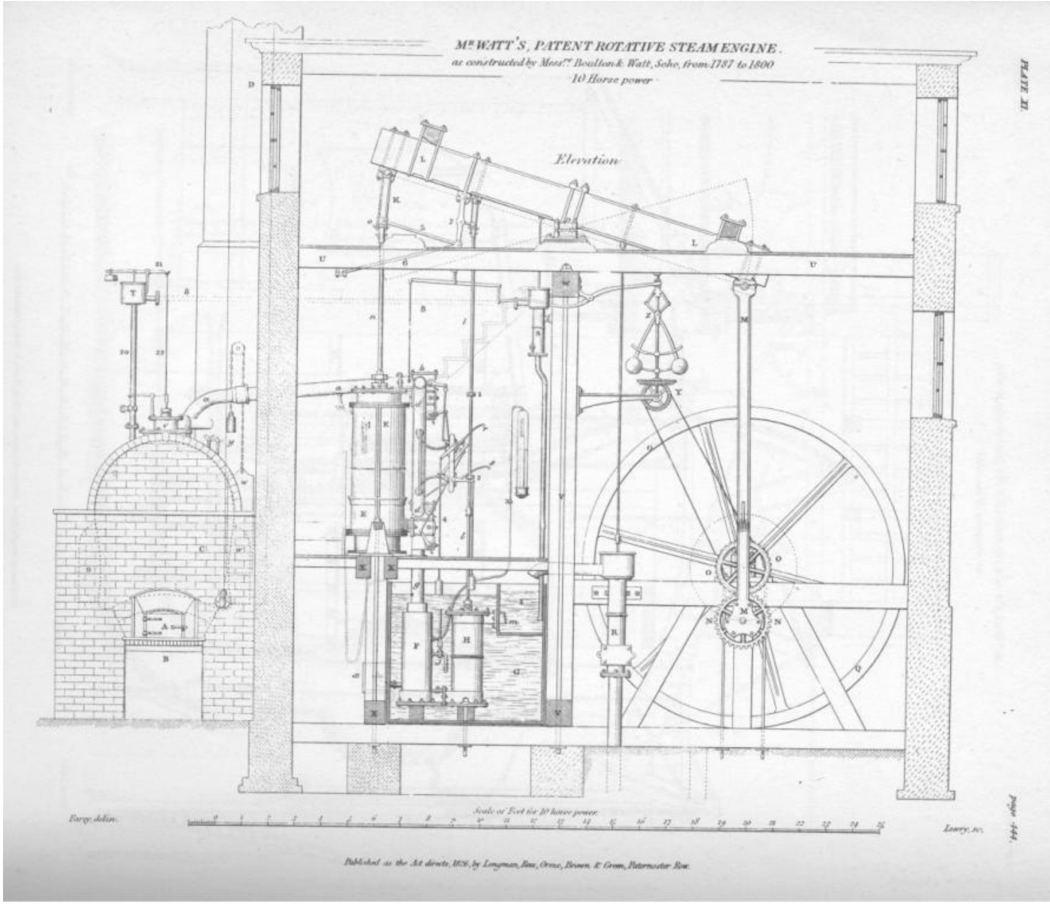
were industrial antiquarians studying the books of engineers past. Indeed, they only credited inventors (excluding Watt) who described and explained their inventions verbally. If an inventor could not describe his invention in *words*, he did not *know* about the machine. Thus, according to their historiography, the communication of the steam engine in words was essential to the existence of the steam engine as an object of knowledge. By drawing on texts rather than artefacts in the history of mechanical knowledge, these authors positioned their works on the steam engine as heirs of these historical texts, as expansions of an established genre describing the steam engine.

With the genre’s existence and importance established, the question of what constituted an adequate language for discussing machines emerged. Each complained about Worcester’s vague and imprecise language in *A Century of Inventions*, implicitly seeking a language in which they could effectively describe the engine. Yet Worcester did not fail because he was a bad communicator, but because no adequate public language about machines was available to him. Requiring such a language, these nineteenth-century texts on the steam engine built it themselves, word-upon-word, by using diagrams as ciphers which translated un-verbalized knowledge into explicit knowledge. All included and depended on diagrams for explaining the steam engine and its elements. More technical than illustration, they were usually line-drawing diagrams showing the significant parts of an engine. Normally they depicted specific examples from the historical development of the engine, from Hero of Alexandria's Pneumatica to Watt's Double-Acting Steam Engine, and sometimes beyond. While all included diagrams of the engines as assemblages of parts, some also incorporated smaller diagrams of individual parts or sub-assemblies. On the simpler and cheaper end of the spectrum, the diagrams were small and simple, as in Robert Stuart's *Descriptive History* (Fig. 2.2). At the technical and expensive end, they were detailed and accurate, as in John Farey's *Treatise* (Fig. 2.3).

This diagram-dependence was rooted in contemporary engineering practice in which mechanical knowledge was increasingly created and communicated through mechanical drawings and plans.[108] Making tacit knowledge explicit in a way, the drawings were the 'bridge between knowledge and manual dexterity' (C. Fox 47). This visual medium 'amounted to a novel language for articulating a novel form of knowledge' (J. Brown 201) and was the *lingua franca* of the engineering community.[109] While scholars continue to conceptualize engineering drawings as a 'language', such drawings only make mechanical knowledge explicit to the small communities possessing the intellectual tools to interpret them.[110] In engineering, drawings were left to speak for themselves, as it were, labelled only with numerical dimensions. Outside the engineering community, drawings were incomprehensible to non-specialist readerships. For example, Stuart could not liberate himself from this engineering approach, remaining so heavily dependent on diagrams that Galloway criticized him for leaving 'the reader to discover the principle of many of the machines, by little else than the engraving itself' (vi).

Unlike Stuart's, most works on the steam engine used diagrams as bridges between tacit knowledge of the machine as a physical object and explicit knowledge of the machine

[108] On drawings in eighteenth- and nineteenth-century engineering practice, see C. Fox 45-132; J. Brown. For the importance of drawings to engineering, see Booker; E. Ferguson.
[109] For the role of visual images in the creation of scientific knowledge, see the essays in Baigrie, which privilege image over language (xix).
[110] See J. Brown 201; C. Fox 46.



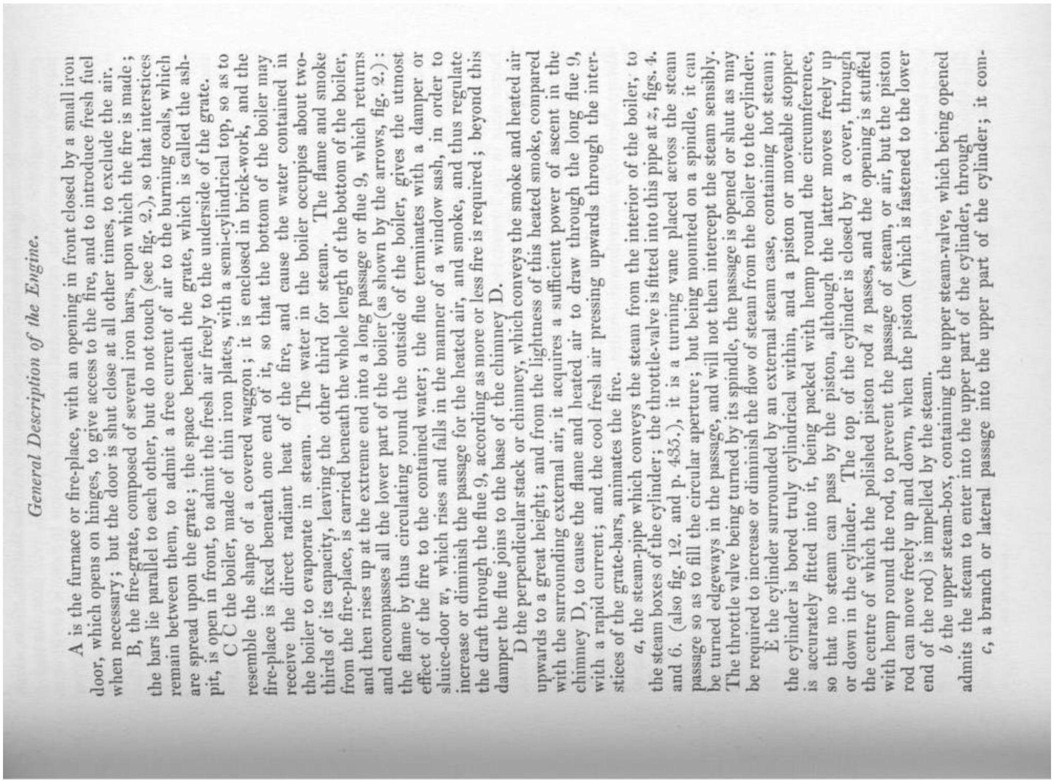


Fig 2.3. 'Mr Watt's Patent Rotative Steam Engine' and accompanying text from John Farey's *Treatise on the Steam Engine* (Plate 11; 445).

expressed in language. Each part in a diagram was carefully labelled with a letter or number then named in the text—*in language*. So words like ‘piston’, ‘cylinder’, and ‘valve’ were visually defined. Sometimes they were merely named, as with Stuart (Fig. 2.2), and sometimes they were then described, as with Farey (Fig. 2.3). At the most basic level, these diagrams served as ciphers translating tacit knowledge to explicit by linking the visual signified with the verbal signifier. Word-by-word then, these texts built a public language in which machines could become the objects of public discourse. And in the ‘cognitive hierarchy’ of Western thought which privileges words in the creation, acquisition, and possession of knowledge, the expression of machines in language implied that they were logical and comprehensible.[111] This translation of technology into text and language counteracted the continuing technological sublime by making the steam engine textual instead of physical, abstracting them from a physical presence which so often produced feelings of the sublime instead of confidence in rational knowledge.

Yet single linguistic units—words—do not a discourse make. Instead, as the definitions of mechanical words became increasingly stable within these texts, the genre turned to an already established discourse to provide a legitimizing and stabilizing framework on which to hang its words: the scientific. Where the early works on the steam engine gave a large place to diagrams, the latter focused on scientific principles. Instead of depending primarily on diagrams to make the reader understand, both the technical treatises of Tredgold and Farey and the popular works by Lardner and Reid grounded their expositions on explanations of the scientific principles by which the engine functioned. Indeed, this merging of mechanical words and scientific language was finally codified into an engineering language by Robert Willis’s *Principles of Mechanism* (1841) and William Whewell’s *Mechanics of Engineering* (1841).[112] Thus their mechanical knowledge and language became part of the institutional structure of public science, granting it legitimacy as public knowledge. By translating machines into diagrams, then into words, then into science, popular technology constructed machines as objects of public knowledge and culture.

The constructed intelligibility of machines had impacts reverberating beyond engineering or manufacturing in early nineteenth-century British culture. It reflected on class structure and social relations and participated in the construction of Britishness and the

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[111] This account of the translation from physical object to diagram to language assumes that people privilege words in the creation, acquisition, and holding of knowledge. Although this ‘cognitive hierarchy’ permeates the history of Western thought, Topper has begun to explore the value of visualization without verbalization for thought, see also Giere.

[112] On their mechanical language, see Marsden, ‘Progeny’.

perception of national supremacy. But it also shaped the 'interpretive community' for natural theology. The existence of popular technology helps account for the difference between Campbell's Bushmen and the Englishmen with whom natural theology was so popular in the 1830s. Through their external and internal media, through books and language, these expositions of steam engines constructed machines as intelligible to the general public. They trained the English mind to see logic rather than magic in a machine. Thus when an Englishman on a heath found Paley's watch, his culturally-situated conviction was that the watch was intelligible rather than magical, and thus the product of design. Popular technology implicitly repaired the weakness which Campbell's anecdote identified in natural theology, guaranteeing the possibility of the argument from design. Once formed, this system of cognitive response could then be transferred onto contrivances in nature. Indeed, the idea, implicit in these textual expositions of steam engines, that machines could be 'read' linked popular technology to natural theology which had long sought to read the book of nature, an analogue to the book of revelation. These expositions implicitly relied on the special place reading and literacy had for Protestants, but they also magnified the power of books and reading by expanding the territory they could explain. The possibility of reading machines reflected dialectically back on the reading metaphor within natural theology, offering it support and corroboration by making design readable—by making design comprehensible. Popular expositions of technology thus reinforced natural theology as a genre by putting understanding into language, by reinforcing the idea that it is possible to understand the design of physical objects through reading about them.

The Theological Machine: The God-of-the-Gears

My preliminary hypothesis, that popular technology facilitated natural theology in the 1830s, depends on an *a priori* prediction about the design argument's psychological viability and logical structure. But there is also corroborating historical evidence that connects expositions of technology and the argument from design. Its 'interpretive community' shaped by popular technology, natural theology reflected popular technology's constructions of machines by internalizing the ways mechanical design was explained. Natural theology described objects and explained structures and processes in nature in the same way expositions of technology described and explained machines. Like popular technology, natural theology conceptualized design by focusing on order and fitness, on how parts fit together, and on how means are adapted to ends.

Where earlier natural theology was built around contrivance and later natural theology around the laws of nature, design in the 1830s centred in 'adaptation'. This 'adaptation' had a staggering diversity of meanings and applications. Adaptation could be:

1) of means to ends
2) of parts to each other
3) to external conditions and laws
4) of fitness to do good to animate beings, or humans specifically
5) to the human mind.

In post-Darwinian thinking, 'adaptation' is usually understood as the *process* by which an animal is suited to its environment. Reading backward through evolutionary theory in which adaptation is a process with a natural source, today's readers interpret natural theology's 'adaptation' as referring to supernatural action, to providential intervention to 'adapt' nature to the good of human beings. But the Bridgewater Treatises focus on 'adaptation' not as a process, but as a quality of nature. Bell and Chalmers see design when parts are in the right relations to each other.[113] For Roget and Whewell, design is when the construction of every part is adapted to its material conditions.[114] Design denotes the adaptation of means to ends for Buckland, Kirby, and Prout.[115] Only Prout and Kidd focus specifically on how nature is adapted to and for man's benefit. Beyond the Bridgewater authors, Babbage, Brougham, and Crombie see design as the adaptation of means to ends, but Crombie and Brougham emphasize the relationship of parts to each other in the accomplishment of ends.[116] Rather than jumping to supernatural explanations for nature, then, these texts focus on the existent and static relationships between parts of nature.

Their definition of design as the adaptation of means to ends suggests a natural theology based on purpose, function, or *telos*. Indeed, the argument from design is often referred to as the 'teleological argument'. Yet in practice, their explorations of design focus on how means fit together, rather than on the ultimate purposes they achieve. Despite the diversity of the Bridgewater Treatises, they almost all take this approach, evident in how they present different areas of nature. In the non-biological sciences, Chalmers explicates the mutual fitness of the human mind and society. External things 'bear a fit relation to the laws and properties which are within man' (1: 43) while the human conscience fits perfectly into 'the mechanism of human society' (1: 170). Turning to the physical world, Whewell

[113] Chalmers 1: 24; Bell, *Hand* xi.
[114] Roget 2: 443; Whewell, *Astronomy* 29.
[115] Buckland 1: 76; Kirby cv; Prout 'Introduction'.
[116] Babbage, *Ninth* 31; Brougham 23-24; Crombie 1: 399.

explores the adaptation 'of construction to conditions' (*Astronomy* 29) between the earth and universe. Describing how independent things, like the plant lifecycle and the length of a year, fit together, Whewell asks: 'who constructed these three extraordinarily complex pieces of machinery, the earth with its productions, the atmosphere, and the ether? Who fitted them into each other in many parts, and thus made it possible for them to work together?' (*Astronomy* 141). In a seemingly bizarre combination of chemistry, digestion, and meteorology, Prout describes chemical substances as 'the endless repetition of exactly similar parts' (87).

But human and animal bodies were the favourite sites of such discussions in the nineteenth century. Under the influence of Cuvier's focus on the functional relationships of different anatomical parts, British natural theology gloried in explaining how the parts of animal bodies fit together.[117] Describing the hand's anatomy and how it fits with the rest of the body, Bell shows how its construction is adapted to the physical laws of the universe and to the functions of the animal body. While Bell focuses on the mechanical fitness of one unit to the whole, Roget presents animal physiology as an arrangement of perfectly adapted components—mechanical, vital, sensorial, and reproductive. Each species has the same general structure, with only slight variations of each component to fit conditions.[118] These repeated relationships between parts and parts-of-parts point to a unity of composition—and composer—for Roget. Fossilized animals receive the same treatment from Buckland. Although exploring all types of adaptation, he looks at a single fossilized animal bone or structure and tracks it across different species to show how it was adapted to the physical conditions of the geological epoch in which that animal lived. But he also assembles and disassembles the parts of single animals, like the megatherium, noticing how strange the parts seem until they are put together, where they fit perfectly to piece and purpose.[119] While Kirby gets lost in entomological minutiae, he consistently shows how bugs play an important function within the larger ecosystem. Thus the Bridgewater Treatises, with the exception of Kidd, argue *for* adaptation in nature by looking at the arrangement of nature, at how the parts of nature fit together. Indeed, the implementation of the Bridgewater bequest assumes that nature can be divided into different parts discussed in separate treatises and then reassembled into one coherent and convincing eight-part whole.

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[117] On anatomy, structure, physiology, and function in seventeenth- through nineteenth-century natural theology, see Bynum.
[118] When Roget focuses on the organization of species in taxonomy, he joins the Linnaean vein of natural theology that claims that the possibility of classifying all species into an organized taxonomy implies the existences of an organizer.
[119] Buckland 1: 139-164.

The assumption and description of nature as a series of parts adapted to each other was codified into a theory of natural theology offered by George Crabbe at the end of the decade. His *Outline of a System of Natural Theology* (1840) may use the word 'adaptation' in every way listed, but his theory is based on the conception of 'adaptation' as parts fitting together. Understanding natural theology's approach as tracing the fitness of parts to each other, Crabbe claims that the argument from design is built on the assumption that parts are independent of each other. Making 'the principle of the original independence of multitudes of phenomena in the different parts of nature' his 'leading argument' (xiii), Crabbe demonstrates the truth of this principle through evidence from nature.

Thus natural theology explained nature in the same way that popular technology explained machines. Expositions of the steam engine described and explained the components of the engine and then explained how they fit and worked together. The Bridgewater Treatises did the same thing with nature, focusing on how the parts of nature fit together. On popular technology's pattern, natural theology used 'design' as a description of physical and natural objects, rather than using it to describe God's action in relation to nature. The Bridgewater Treatises even neglect what popular technology neglected: purpose. With limited vision, expositions of the steam engine ignored the purposes of the engine, describing only the functions of each part in the larger machine. While the Bridgewater Treatises discussed the functions each component fulfilled within the natural system, they generally neglected the *telos* of that natural system in their arguments.

Natural theology's shift from 'contrivance' and *telos* in the early century to 'adaptation' and arrangement in the 1830s reflected the connotations of 'contrivance' built by popular technology. Focusing on 'contrivance' rather than broad 'mechanism', Paley had taken up relatively small objects in nature, abandoning the vastness of the celestial mechanism so important to earlier natural theologians.[120] A few decades later, natural theology responded to a developing nuance of 'contrivance' in its shift towards adaptation. In expositions of the steam engine, a 'contrivance' was a sub-assembly that served a certain purpose, but that the writer did not fully explain. As natural theology shifted toward the adaptation of parts to each other, it shifted away from a natural theology dependent on the purposes or functions of an assembled unit (a contrivance). In practice, then, 1830s natural theology was more concerned with order and fitness than with purpose and benefit. It focused on immediate causes and structures, not primary or final causes. Thus natural

[120] For a discussion of the discursive similarity of 'mechanism' in technological language and natural theology, see Marsden, 'Progeny' 403. On the importance of astronomy for earlier natural theology, see Gascoigne.

theology mediated natural objects through the same techniques which popular technology used to describe mechanical design.

The similarity went even deeper. Natural theology shared popular technology's techniques for explaining the *operations of* nature, not just *constructions in* nature. Popular technology texts considered the physical parts of machines and tried to explain how those parts worked together by looking at the laws which governed those movements. In the same way, the natural theology of the 1830s first established how parts fit together and then discussed how they functioned through reference to the laws of nature. Historically, the laws of nature had been a contested point in natural theology. Crombie, for example, argued against using the laws of nature in explaining the universe because attributing the existence of the world to natural causes (laws) was atheism. Chalmers and Kirby also rejected the laws of nature for natural theology because it was too easy to ascribe the origin of the universe to them. But while Crombie found design in the 'concurrences of means, various and complicated, towards the production of effects' (1: 399), Henry Brougham included function, arrangement, and 'adaptation to mechanical laws' (30) in his definition of design. Indeed, many authors used natural theology's foundation in the analogy with human design to incorporate natural law into their definitions of design. Chalmers and Whewell distinguish between human and divine design because humans do not create the laws by which their machines work, Bell observes that natural design satisfies human conceptions of the laws and principles of mechanics and hydraulics, while Roget uses the diversity of natural machines working according to the same laws to argue for the unity of design in nature.[121] While some have argued that this turning to natural law damaged the public celebration of natural theology because it denied the value of contrivance (Ellegård 128), the concept of adaptation was actually capacious enough to incorporate law into natural theology. Not theoretically incompatible with teleology, natural law could be formulated in terms of adaptation: law could achieve God's intended plan for the universe, guaranteeing that all things continued to serve their purposes.[122]

This way of incorporating laws into natural theology was taken up by many of the Bridgewater authors. While it primarily described how parts fit together, 'adaptation' was also applied in the 1830s to how something worked because it fitted with external conditions, i.e., the laws of nature. They often represented nature as functioning through uniform natural laws (what popular technology would call principles) or showed how natural designs were

[121] Chalmers 1: 16, 22-23; Whewell, *Astronomy* 360; Bell, *Hand* 269-270; Roget 2: 625.
[122] On the compatibility of law and *telos*, see Ospovat, 'Perfect'; Topham, 'Teleology' 151.

adapted to external conditions. Whewell, for whom nature is ‘a collection of facts governed by laws’ (*Astronomy* 3, vi), traces the adaptation ‘of construction to conditions’ (29) of nature’s parts. For example, he explains how the eye and the *camera obscura* are constructed according to identical laws (128-137). Ultimately, his goal is to demonstrate how laws themselves are adapted to their roles, giving ‘evidence of selection, design, and goodness’ (9).[123] Showing how animal bodies were adapted to the conditions of their geological epochs, Buckland depends on the uniformity of the laws of nature to discover how those parts fit together. Indeed, despite the turbulence of geological changes, the uniformity of laws points to design for Buckland (1: 49). For Bell, studying the body’s structure leads the observer to see how that structure corresponds to external nature and its laws, ultimately reflecting the goodness of God’s design (*Hand* 3-11). Bell augments this observational process by discussing the principles and laws by which man-made contrivances work then showing how the animal frame functions according to the same laws. Thus, the relationships of its parts match the laws of mechanics. Defining physiology as the identification of the laws which connect cause and effect and which relate means and ends, Roget maintains that all the basic scientific principles of architecture and dynamics are exemplified in the construction of the animal fabric (1:21-23, 372). And, like Buckland, he emphasizes the uniformity of the laws of nature (1: 6). Just as the more technical writers on technology, like Farey, Tredgold, and Lardner, structured their works around principles rather than specific structures, Prout organizes his seemingly eclectic *Chemistry, Meteorology, and the Function of Digestion* around the principles of heat and light, unifying these diverse topics through the function of heat and light within them. Finally, Crabbe and Whewell go one step further by seeing the laws of nature metaphorically as a structure, with the different laws becoming the parts that were adapted to each other.[124]

Despite its relative omission of mechanical design metaphors, Baden Powell’s *Connexion of Natural and Divine Truth* (1838) is the culmination of this incorporation of laws into natural theology through the concept of adaptation. With complex logic, Powell argues that final cause (*telos*) should not be the foundation of natural theology. Logically codifying what the Bridgewater authors did in practice, Powell suggests that ‘“final cause”’ should be replaced with ‘“adjustment,” “fitness,” “arrangement,” “adaptation”’ (124). Consistently looking at the ‘fact’ of adaptation and arrangement, Powell recognizes design

[123] For perspectives on Whewell and laws, see Brooke, ‘Natural Law’ 88, ‘Scientific Thought’ 47; Topham, ‘Teleology’ 151.
[124] Crabbe 10-11, 404; Whewell, *Astronomy* 18.

'not for the *work* it does, but for the *skill* displayed in its *construction* and *operation*'.[125] He values the way things are put together, rather than what purposes they serve. But Powell's primary evidence is the actual laws and how they fit together rather than physical structures like the hand or the animal body. For him, design is evident 'when phenomena can be traced up to their determinate laws' (116-117). To Powell, looking at the arrangement of the material parts of nature is merely a way to discover the laws behind them. Ultimately, the laws themselves fit together into 'a self-supporting equilibrium, like the stones of an arch' (108-109), becoming the structure studied by natural theology.

Dichotomizing natural theology as based either on supernatural intervention in nature or on the natural uniformity of the laws of nature, scholars have located a historical shift from supernatural to natural in the 1830s. Cannon sees the 1830s as the stage of a huge debate over miracles and their evidential value, while Corsi traces in the 1830s the first tentative introductions of naturalistic explanations into natural theology. But while 'adaptation' smacks of a supernatural design argument, its application in the 1830s was to a *natural* design argument. As a type of evidence, adaptation linked contrivance and law because it focused on the construction and operation of nature, not on first or final causes. This adaptation, informed by approaches to describing and explaining machines, helped incorporate the laws of nature into natural theology in the face of fears about determinism and materialism. The use of laws and principles to describe and explain how machines worked but not where they came from sanitized the laws of nature for a natural theology built on adaptation. Thus adaptation formed a bridge between contrivance and law, while firmly rooting natural theology in evidence from the natural constructions and operations of nature.

Misunderstanding 'adaptation', many readers of natural theology characterize it as presenting a God-of-the-Gaps, that jumps automatically to a supernatural explanation when it runs across something it cannot explain naturalistically. According to this stereotype, natural theology offers up these mysteries to the reader as its evidence. But the 1830s natural theology of adaptation challenges this characterization. Focusing on concrete arrangements and adaptations in nature, it depends on what is intelligible and natural, not on what is wonderful or mysterious, borrowing the lens provided by popular technology. By focusing on nature's detail, it largely leaves the inference of design up to the reader. Arguing *for* adaptation, it focuses on what can be comprehended in nature, letting the reader complete the argument *from* adaptation for divine involvement. Thus the explainable is part of the text and

[125] On the 'fact', see Powell 126, 171, 183, 284, 287. On skill, see Powell 292.

part of nature, while the supernatural is provided by the reader. Theirs is not a God-of-the-Gaps, but a God-of-the-Gears.

It has become a critical and historical assumption that mechanistic understandings of nature faded when the Enlightenment did. And because natural theology was based on a mechanical metaphor for nature, it must have faded with the eighteenth century also. But the popularity of natural theology in the 1830s challenges this narrative and opens the question of how natural theology related to mechanical metaphors and machines. This chapter has traced the importance which meanings of machines had for the design argument in the 1830s. It suggests that mechanical metaphors could have more than one relationship to natural theology—that they had a different relationship in the 1830s than they did with earlier mechanistic science. The natural theology of mechanistic science assumed that natural objects actually function like machines because they move by the mechanical contact of parts according to the laws of mechanics. But the natural theology of the 1830s depended on new meanings of machines for its cultural and psychological power. A person's inference to design when looking at a man-made or natural object depends, as Campbell's African anecdote demonstrated, on a culturally-constructed set of intuitions, feelings, and practices. Campbell's Bushmen reacted to his watch in the mode of the technological sublime, cancelling the power of the design argument. This same mode existed in England, but was counteracted by the genre of popular technology. Through their form, these texts constructed machines as intelligible rather than magical. Expositions of the steam engine carefully built a language for machines that meant that everyone could know and discuss them. Analytically, this emphasis on intelligibility enabled the design argument by engraining the inference to design more deeply into the cultural set of intuitions, feelings, and practices. Natural theology's absorption of the machine's meanings in the 1830s is evident in its emphasis on adaptation, on how parts fit together and how they work according to the laws of nature. By absorbing mechanical intelligibility to present a God-of-the-Gears, 1830s natural theology reveals that mechanical metaphors remained central to design and to understanding nature, but also that they depended on different meanings of machines than did earlier natural theologies. Thus mechanical metaphors went below the logical surface of science and theology to shape the very thought process of design.

The importance of mechanical intelligibility for design challenges a major notion in the intellectual history of the Western world: the twinning of secularization and disenchantment. In the early twentieth century, Max Weber argued that the Western world's secularization went hand-in-hand with the disenchantment of the world.[126] As soon as people ceased to see nature as magical, as soon as they stopped seeing a sublime God-of-the-Gaps, secularization set in. Joining several other critical voices, this chapter contradicts this view.[127] Emphasizing the intelligibility of nature, 1830s natural theology disenchants nature for religious purposes. Enchantment, like that of the African Bushmen, threatened the power of the argument from design. This not only challenges an accepted historical narrative, but challenges the modern secular assumption that religion and rationality are constitutionally incompatible.

[126] Weber 13-17.

[127] Among a growing crescendo of objections to Weber's narrative, Jager's *The Book of God* questions the narrative of secularization's explanatory power by looking at the relationship between design and writers of the Romantic period. Alex Owen's *The Place of Enchantment* contradicts Weber's history by tracing the growth of spiritualism in the late nineteenth century. Finally, George Levine's *Darwin Loves You* considers how Darwin's theories can be reread as re-enchanting the natural the world.

CHAPTER 3

Taxonomy, Topography, and Technology: Integrating Nature and Machines in the 1830s

Established by expositions of steam engines, the intelligibility of machines was crucial to natural theology's plausibility structure, but did not complete it. Natural theology also required other meanings of machines. As with intelligibility, an objection to the design argument reveals one of these significances: for the design analogy to work, the natural and the artificial had to be perceived as similar. Although his critiques were relatively ignored in the nineteenth century, David Hume's *Dialogues Concerning Natural Religion* (1779) uncovers this pillar on which natural theology rested.[1] Cleanthes, Hume's natural theologian character, assumes that 'it is by no means necessary, that theists should prove the similarity of the works of nature to those of art; because this similarity is self-evident' (63). But Philo, Hume's devil's advocate, consistently denies this similarity, concluding that 'the world plainly resembles more an animal or a vegetable than it does a watch or a knitting loom' (87).[2]

Early nineteenth-century critics of design reiterated this objection when they reviewed Henry Brougham's *Discourse on Natural Theology* (1835). A. C. G. Jobert rejected the design analogy because it 'compares things between which no analogy subsists' (25), noting that he can understand the making of a watch but not a living creature (26-28). George Ensor mocked science and engineering for failing to 'reproduce one of the simplest organic products by an artificial combination of its elements' (15), thereby denying the similarity between natural and artificial. Like Hume, they attacked the mechanical design argument where they thought it vulnerable: the aptness of its central metaphor. While a metaphor assumes a difference between its two terms, it also requires points of similarity between them, which theorists call its aptness.[3] Along with conventionality, aptness determines a metaphor's success or plausibility.[4] Hume, Jobert, and Ensor reluctantly conceded the design analogy's conventionality but contested its aptness.

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[1] On Hume's nineteenth-century reputation, see Knight 26.
[2] See Parts II-VII of the *Dialogues* (51-91).
[3] Metaphors are more apt 'to the extent that their terms occupy similar positions within domains that are not very similar to each other' (Tourangeau and Sternberg 27).
[4] A successful metaphor is processed easily and quickly. For an approach combining conventionality and aptness, see Thibodeau and Durgin.

The plausibility of natural theology, then, depended on the aptness of the design analogy, which depended on the similarity between natural and human-made objects, between nature and machines. In the seventeenth and eighteenth centuries, that similarity had been established through the mechanization of nature within natural philosophy. But as the nineteenth century dawned, biological life began to replace matter as the centre of scientific pursuit.[5] Although mechanical metaphors for nature were never explicitly and wholly rejected, they were no longer as useful for scientists fascinated with life and vitality.[6] Thus the similarity between nature and machines was often no longer reiterated in mechanical constructions of nature. The plausibility structure that made design possible in the seventeenth and eighteenth centuries was quickly becoming derelict in the early nineteenth century. So accounting for the plausibility of the design argument in the 1830s involves answering the following questions: how were machines and nature understood and how was their relationship constructed? How was the similarity of nature and machines established or reiterated in the 1830s?

Organized around these questions, this chapter argues that the renovation of natural theology's plausibility structure was accomplished by two unlikely candidates: defences of the factory system and industrial travel narratives. But instead of working on the meanings of nature, they worked on the meanings of machines. Instead of mechanizing nature, they naturalized machines. Responding to specific strains of criticism within the Factory Reform Movement of the 1830s, defences of the factory system including Andrew Ure's *Philosophy of Manufactures* (1835) and Charles Babbage's *On the Economy of Machinery and Manufactures* (1832) and industrial travel narratives like George Head's *A Home Tour through the Manufacturing Districts of England* (1836) integrated machines into nature, constructing the mechanical and the natural as fundamentally similar.

In calling this relationship 'constructed', I emphasize the activities and tools utilized in the making of meaning. A physical structure is determined as much by the tools used as by the materials available or the function intended. In the same way, the relationship between 'machine' and 'nature' is partially determined in these texts by the tools used to build the two concepts. The popular literature of technology by Ure, Babbage, and industrial tourists borrowed instruments from the toolboxes of the investigators and connoisseurs of nature to describe—and to construct—the meanings of machines. Specifically, they borrowed topography, the picturesque, and taxonomy. Grouping topography and the

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[5] On this shift, see Odom.
[6] For this critical commonplace, see Dijksterhuis; Gascoigne.

picturesque together then proceeding to taxonomy, this chapter argues that 'nature' and 'machine' began to blend together because produced through the same tools, establishing a foundation for a natural theology reliant upon their similarity.

Nature versus Machines?

A fundamental dissimilarity between nature and machines is often assumed today. Influenced by Romanticism, technophobia, and Green movements, many see nature and machines as opponents, with nature the victim of technology. Yet this dichotomization of the two terms has more to do with how they are understood than with how they are. While nature and machines exist out there, the way we understand them and their relationship is constructed within a specific time and in a specific place by an array of social and cultural factors. They could have been different—and they were. Most of this chapter will explore one formulation of this relationship, but this brief section will establish the constructed-ness and contingency of both terms as a philosophical foundation for my argument.

Although both are central to Western civilization, neither 'nature' nor 'machine' have essential meanings, but are culturally constructed in opposition to something else. The only consensus about 'nature' as a term and an idea is its ambiguity.[7] Controversially asserting that '*there is no nature*' (38), Alan Liu denies that nature has an 'essence' or a universal definition. Instead, nature is just 'the name under which we use the nonhuman to validate the human' (38).[8] Like Liu, I am not denying that something out there exists, but am suggesting that when we talk about 'nature' we are already talking about the meanings we give to it. Recognizing the term's mutability across time, C. S. Lewis suggests that the best way to understand any particular meaning of 'nature' or 'natural' is through its opposites: natural versus unnatural, nature versus grace, natural versus supernatural, natural versus interfered with, etc.[9] Infinitely flexible in meaning, 'nature' has largely been defined against humanity

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[7] For an intellectual history of 'nature' that links the concept with the (scientific) study of natural objects and laws, see Collingwood. For a consideration of the constructions of nature through history, see Evernden. For the historical centrality of the concept of nature and of the question of the relationship of nature to humanity in Western thought, see Glacken. For one of the most important constructivist considerations of what 'nature' meant at the end of the twentieth century, see Haraway. For a history of the concept and the development of the word 'nature' from its etymological roots in Greek, through the Middle Ages, up to the early twentieth century, see Lewis 24-74. For a philosophical analysis of the term and its meanings, with special attention to the politics of the idea in the 1990s, see Soper. For the changing attitudes about the relationship between humans and nature, see K. Thomas; and between nature and society, see the essays collected in Teich, Porter, and Gustafsson.

[8] Ecocritic Timothy Morton also suggests that 'nature' is 'an arbitrary rhetorical construct, empty of independent, genuine existence behind or beyond the texts we create about it' (21-22).

[9] Lewis 43, 43-72.

or against culture in the Western tradition.[10] Yet each reiteration of this opposition is inflected by time and place, constructed according to contemporary concerns and discourses. In the context of a deepening ecological crisis, 'nature' today is often understood through a *via negativa*: popularly, it is all that is neither human nor generated by humans, according to Kate Soper.[11] In the mid-1850s, John Stuart Mill noticed the same popular significance of 'nature', but in that moment the understanding was rooted in the Romantic perception of man's exclusion from nature under the conditions of industrialism and Enlightenment rationality.[12] Yet Romanticism was not the only cultural context for understanding the term: 'nature' was also the central object of Victorian science according both to its practitioners and to twenty-first century historians.[13] But while the Victorians may have believed that there was a real nature out there, historians investigate how the nineteenth-century idea of 'nature' was produced by and within certain epistemological, sociological, and religious structures.

The meaning of 'machine' is also ambiguous and historically flexible, as my project reflects. What Collingwood says of the concept of nature applies to the concept of the machine: it 'depends for its existence on something else' (176). There was never a moment when the 'machine' was a blank canvas of meaning waiting to be written on by cultural forces. Emerging as an object of public culture in the early nineteenth century, its meanings were constructed by a complex set of ideas, practices, and contexts. Like nature, it is understood through opposition with other concepts, or, stated more softly, understood along its borders with other concepts. Bizup and Ketabgian each identify a boundary: culture and humanity.[14] The 'machine' is thus multi-faceted, with multiple limits along which it is constituted. Nature is one of them. But, as with culture and humanity, this border is not

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[10] Glacken; Latour.
[11] Soper 15.
[12] Mill 373-375. On this Romantic view of nature, see Adorno 83-84; Bate 38-42; Lewis 72-73.
[13] Indeed, the critical apparatus concerned with nineteenth-century science, religion, and literature focuses on the different mechanisms for mediating nature's meanings, evident in the titles of these studies, like John Brooke and Geoffrey Cantor's *Reconstructing Nature: The Engagement of Science and Religion*, Sally Shuttleworth and John Christie's *Nature Transfigured: Literature and Science, 1700-1900*, Geoffrey Cantor's *Science in the Nineteenth-Century Periodical: Reading the Magazine of Nature*, Bernard Lightman's *Victorian Popularizers of Science: Designing Nature for New Audiences*, Jim Endersby's *Imperial Nature: Joseph Hooker and the Practices of Victorian Science*, and Jennifer Tucker's *Nature Exposed: Photography as Eyewitness in Victorian Science*.
[14] Pushing back against the opposition of machines and culture, Bizup's *Manufacturing Culture* (2003) shows how machines were represented as part of culture by many of the texts studied in this chapter while the late nineteenth-century intelligentsia carefully opposed it to 'culture', as in Matthew Arnold's *Culture and Anarchy*. Complicating the opposition between humans and machines, Ketabgian's *The Lives of Machines* (2011) suggests that what is human is discovered through looking at the machine/human border, and that both concepts deeply structured and informed each other in Victorian literatures.

static but drawn differently through time. While a tradition stretching through William Wordsworth, Matthew Arnold, Raymond Williams, and Al Gore presents ‘nature’ and ‘machines’ as diametrically opposed, other traditions and discourses have articulated the relationship between them differently. The remainder of this chapter explores one formulation of this relationship and its religious ramifications.

Naturalizing the Mechanical: Topography, the Picturesque, and the Landscape

Before the mid-eighteenth century, the ‘machine’ was often understood to be a watch, a microscope, or an inclined plane. But with the Industrial Revolution, discussions of the ‘machinery question’ concerned the factory, a complex collection of small machines and labourers organized around a motive power, often a steam engine. How to present the factory-machine was highly contested, articulated through discourses, cultural forms, and social patterns from a broad range of concerns (Gray 11). One frame for understanding it was comparison with nature. During the factory reform movement of the 1830s and 1840s, critics sought to present factories as unnatural. Styling himself a factory cripple, William Dodd asserted that factories maim children by stunting their natural growth, concluding that factory work is not intended by God (5). A medical man, Peter Gaskell maintained that the factory system harms the ‘natural and proper order of things’ (59-60), resulting in ‘unnatural arrangement’ within family structures (64).[15] While they seldom conceptualized the factory as directly harmful to natural objects, they saw it as opposed to the natural order of God.[16] Yet other constructions of the meanings of factories answered this specific objection. Babbage’s *On the Economy of Machinery and Manufactures*, Ure’s *Philosophy of Manufactures*, and lesser known factory tourism literature presented factories as natural by looking at them through available visual and epistemological frameworks: topography, the picturesque, and taxonomy. Not only did they defend the factory system, but they naturalized the machine, assimilating nature and machines by integrating machines into the physical landscape and into the order of nature. After introducing the genre of industrial travel

[15] Others maintain this unnaturalness: Fielden iii, 6, 16, 34; Wing iv. Scholars now consistently refer to this discourse of unnaturalness within discussions of factory legislation, see Berg; Gray 53, 61-62, 73, 79-81, 139.

[16] Later in the century, Ruskin would make the same move in *Fors Clavigera* (1871-1874) and *The Storm-Cloud of the Nineteenth Century* (1884). The opposition between nature and machine was made concrete at the end of the century in the controversies over the Manchester Water Company’s scheme to damn Thirlmere as a reservoir to provide Manchester with water. Although the scheme was successful, Ritvo has traced one of the sources of modern environmental activism in the opposition to it.

literature and its emergence from the culture of British travel, this section will explore how such texts naturalized machines through the topographic and picturesque modes.

Another sub-genre of popular technology, books by Ure and Babbage in the mid-1830s and industrial travel narratives in the 1830s and 40s explained the factory and factory system to general audiences. Babbage's *On the Economy of Machinery and Manufactures* and Ure's *Philosophy of Manufactures* were influential, controversial, and highly read during the loudest part of the debate about the factory and machinery questions.[17] Industrial travel narratives published when factory reform was well on its way in the 1840s allowed Victorians to articulate their subjectivity in terms of factory products while the texts also 'constructed and made sense' of the factory system to their readers.[18] Where popular technology on the steam engine frequently used a historical narrative to make its subject interesting and important, these texts on the factory mobilized the forms and narratives of travel and tourism to unify, justify, and sanitize their often gritty topic. The implications of English travel and tourism were essential to the goals of these texts: through travel, they presented factories as an organic part of the natural and national landscape of Britain.

During the modern period in Britain, travel has been an important and complex cultural form, both in its international and domestic varieties. From the Renaissance onward, international travel was a significant source of culture and of knowledge in politics, science, and business.[19] Yet domestic travel and home tourism also played an important role in the development of national identity through the experience and celebration of England's landscape, industry, and agriculture.[20] While tourism motivated by natural scenery developed around the end of the eighteenth century, home tourism developed much earlier, registered in the travel accounts travellers seemed compelled to supply from the sixteenth century onwards.[21] These accounts reveal that visiting industrial sights was not a new phenomenon: eighteenth-century travellers like Celia Fiennes, Daniel Defoe, and Arthur Young visited them while also visiting towns, estates, and natural scenery. Indeed, Defoe and Fiennes were often more impressed with industrial sights than with natural ones.[22] In the late eighteenth

[17] Here is evidence of Ure's impact: the second edition of Peter Gaskell's highly-cited *Artisans and Machinery* (1836) is tailored to respond to Ure's representation of factory life (332-22); later factory visit journalism by Harriet Martineau and others was written in conversation with Ure (Farina 53); and Karl Marx and Frederic Engels implicitly responded to it (Edwards; Zimmerman 20-23).
[18] For industrial subjectivity, see Farina; for making the factory intelligible, see Morus, 'Manufacturing'.
[19] For Enlightenment travel and knowledge, see Livingstone and Withers. For travel and the acquisition of 'culture' in the nineteenth century, see Buzard.
[20] For the link between tourism and English nationalism see Andrews; Broglio; Moir; Ousby.
[21] On British home tourism and its narratives, see Moir.
[22] Moir 35-46.

century, what has been called technological or industrial tourism became an important part of home tourism, both educating and entertaining the upper classes on visits which celebrated the industry of the nation.[23] Mixing 'objects of scientific curiosity, aesthetic beauty and mechanical ingenuity' (C. Fox 392), these tours encouraged travellers to look at industry through the same lenses that they looked at nature: the picturesque, Romantic, and sublime.[24] Even though home tourism faded in popularity as the 1815 defeat of Napoleon at Waterloo meant the re-opening of Europe to British travellers, home tourism accounts continued to be published, including both personal narratives, like Sir Richard Phillips's *Personal Tour through the United Kingdom* (1828), and educational texts, like Isaac Taylor's *Scenes of Wealth, or Views and Illustrations of Trades—Manufactures—Produce and Commerce—for the Amusement and Instruction of Tarry-at-Home Travellers* (1826).

As the century rolled on toward the crowning of Victoria, new motives for visiting factories and new models for reporting those visits emerged. Rooting his *Philosophy of Manufactures* (1835) in a tour of factories, Ure signals that travel organized solely around factories had begun. While not producing traditional travel narratives, both Ure and Babbage present the factory through the established cultural forms of travel and tourism. In his introduction, Ure carefully explains that he gathered his information about manufacturing 'principles and processes' on a 'survey' or a 'tour of verification' of several months through Lancashire, Cheshire, Derbyshire, etc. (viii, ix). He hopes that his work will serve as a 'guidebook' (viii) for others interested in learning about factories first-hand. Although he does not say so explicitly, Babbage's *Economy of Machinery and Manufactures* was also the product of industrial travel.[25] More importantly, it gives specific instructions for visiting factories, going so far as to provide a factory visit worksheet, complete with a fill-in-the-blank questionnaire (114-118).

Within five years of Ure's *Philosophy*, a genre of industrial travel literature had emerged which extracted factory visits from the general tour and made them the organizing principle of home tourism.[26] While some were critical, like William Dodd's *The Factory*

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[23] Jones, *Industrial*; MacLeod, *Heroes* 63-64; Moir 91. For the unpublished thoughts of John Herschel on his own youthful factory tour in the first decade of the nineteenth century, see Ashworth 630-631.
[24] C. Fox 362-444; MacLeod, *Heroes* 63-64; Moir 91-107.
[25] For Babbage and industrial travel, see Ashworth 630-631; Romano 402; Schaffer, 'Babbage's'. Romano calls Babbage the 'Arthur Young of the Machinery Age' (402) while Morus sees Babbage as taking the reader on a metaphorical tour of the factory ('Manufacturing' 433).
[26] On the genre of industrial tourism, see I. Armstrong 18-36; Gray 132-138; Farina; Moir 91-107; Schaffer, 'Babbage's' 219-224; Tweedale; Waters, '"Fairy"'. I. Armstrong identifies accounts of glass factories as the 'visit genre' with 'recognizable narrative phases' (20, 22); Farina calls the reporting in *Household Words* 'factory-tourism articles' (41); Gray gathers many of these works under the title 'industrial topographies' (138);

System Illustrated in a Series of Letters to the Right Hon Lord Ashley (1842), many celebrated the factory system, as with Sir George Head's *A Home Tour through the Manufacturing Districts of England* (1836), William Cooke Taylor's *Notes of a Tour in the Manufacturing Districts of Lancashire* (1842), and George Dodd's *Days at the Factories* (1843). The genre persisted through the 1840s and well into the 1850s, especially through the factory tour journalism written by Martineau, Dickens, and others for *Household Words* in the early 1850s.[27] By the Great Exhibition of 1851, perhaps the historical apex of technological tourism with tens of thousands of people streaming into London to see the steam engines and industrial products on display, real and imagined machines had moved from the industrial north into the metropolitan heart of London, producing a prolific genre of guidebooks which lumped machines in with products of both the arts and sciences.[28]

These works of technological tourism engaged directly with contemporary political and social preoccupations. Those of the late 1830s and early 1840s responded in varying ways to the machinery question within political economy and to the factory question within parliamentary debates over factory reform.[29] Yet the genre implicitly addressed a single problem for both of these debates: very few people in the Metropolis had ever really experienced the machines, the factory system, or industrial towns. Ure consistently complained that evangelical zeal for factory reform, especially over working hours for children, was based on a false perception of the hardships of industrial life held by people who had never actually been to a factory.[30] He believed that the general parliamentary voter or supper-table discussant lacked the physical and geographical experience of either the factory or the industrial north to make accurate judgments.[31] At a time when developments in transport began to open domestic travel to a broader social cross-section, these industrial travel writers encouraged people to see for themselves before deciding on the factory system's value.

Schaffer goes so far as to call them 'factory guides' ('Babbage's' 220); and Waters calls it 'the industrial tourist tale' when talking of Dickens's form of the '"process article"' and Harriet Martineau's accounts of factory visits published in *Household Words* in the 1850s ('"Fairy"' 217).

[27] On 'factory-tourism articles', see Farina; Waters, '"Fairy"'.

[28] On guidebooks, see Cantor, *Religion* 57-60.

[29] On the machinery question, see Berg; on the factory question, see Gray.

[30] *Philosophy* 302, 374.

[31] Both sides complained about ignorance and inexperience: for pro-industrial, see Cooke Taylor v; for industrial protest, see Gaskell vii.

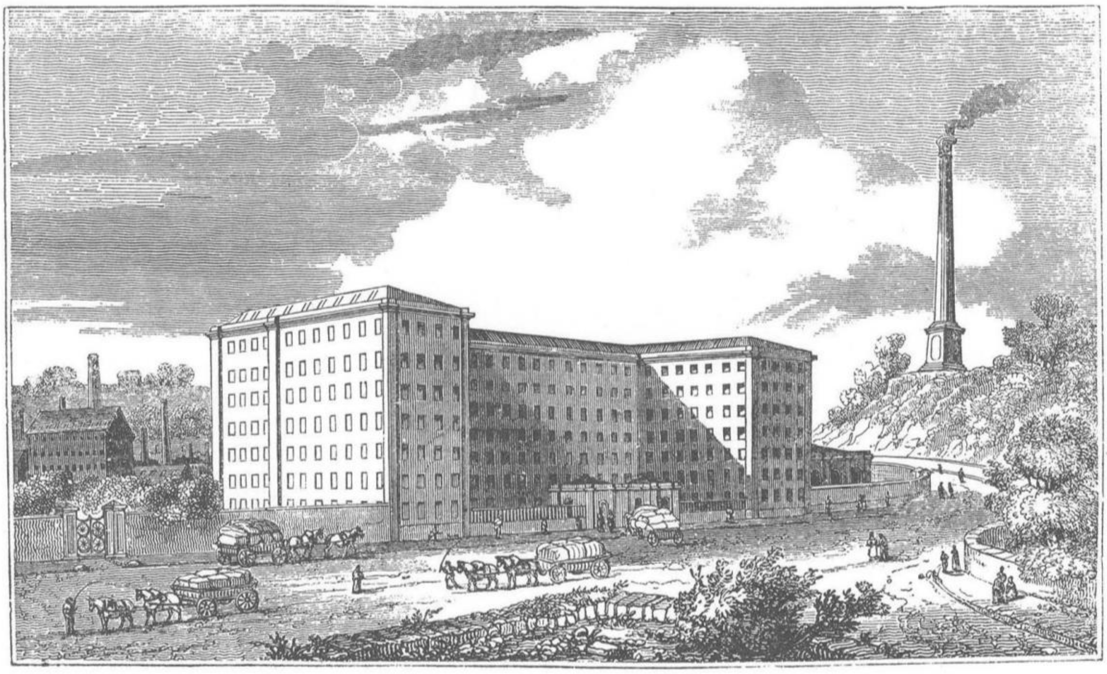

Fig. 3.1. 'Orrell's Cotton Factory, Stockport' from the coverleaf of Andrew Ure's *Philosophy of Machinery and Manufactures*.

Assuming a readership unacquainted with factories, these texts implicitly located their readers in the south, especially in an industrially-ignorant London.[32] In this geographical and intellectual context, the implied reader located the factory in an imagined 'industrial north' that resembled the landscape of Dante's hell rather than the real landscapes of Lancashire or Yorkshire. Revising this vision, industrial travel narratives wove factories into the real English landscape by making them the objects of tourism. They consistently paid close attention to the specific geographies and landscapes of industrial districts. In his *Home Tour*, George Head covers the entire industrial north, from Birmingham to Newcastle. Indiscriminately and unsystematically visiting mines, factories, bridges, museums, and pubs, Head's principle of unity is his transportation from place to place. This emphasis draws attention to the spaces and landscapes *between* the sights he visits, thus mapping the factory system onto the landscape of northern England through his descriptions of canals, roads, railways, and steamship routes. Other authors chose more limited areas. Starting from Manchester, William Cooke Taylor ventures out to the country manufacturing villages of Lancashire, especially Turton and Egerton, to find a 'standard of comparison' by which he can judge whether the problems of Manchester are due to factories or to 'the perturbations of

[32] On the developing contrast between the agricultural, bucolic south and the industrial north, see Wiener 6-7, 41-42.

an immigrant and fluctuating population' (29, 19). Focusing on a small locality, Cooke Taylor fills in the details of Head's narrative, presenting Lancashire 'as a varied county, with connections to an older past' (Gray 134), further cementing the factory system into the English landscape. Although generalizing from a tour of Lancashire, Cheshire, and Derbyshire in *Philosophy of Manufactures*, Ure follows Cooke Taylor by locating an ideal factory system in a country manufacturing village rather than an industrial city (342-355), with Orrell's cotton factory in Stockport as prototype (Fig. 3.1) (109-123).[33] But not all factory travel writing placed factories in the countryside of the industrial north. Leaving cotton to the north (3-5, 14), George Dodd visits other types of factories in London in *Days at the Factories*. Yet like the others, Dodd is specific about the localities of these factories, giving specific directions to specific factories. These are so exact that a reader could walk out of his house in the morning and go straight to any given factory.

Overall, these travel and visit narratives snatch factories from an imaginary landscape and map them onto the real geography and landscape of the nation, whether in the northern countryside or in the Metropolis.[34] Thus they provide a topography of the factory system, fulfilling the *OED Online* definition of topography as 'the science or practice of describing a particular place, city, town, manor, parish, or tract of land; the accurate and detailed delineation and description of any locality' by placing the factory in a real location and describing that location in detail.[35] Yet their geographical mapping was not thorough; it did not systematically list and locate all factories. Instead it was limited and selective, only presenting factories in specific types of landscapes. Besides Dodd, these industrial travel narratives prefer to show rural factories, rather than ones in the great cities of Manchester or Liverpool.

By putting factories in real landscapes, these narratives described the real space *around* the factories. But they also revealed space *within* the factories. Gray observes that 'a characteristic positioning of the observer-author-reader outside the factory gate, or passing through to view the technical marvels inside, constructed the factory as a bounded space' (137). While Head and Cooke Taylor prefer to stay outside, Dodd and Ure enter into the factory, shaping its interior into an organized and orderly space through a topographic vision.

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[33] Orrell's factory also governs Ure's vision of the manufacturing landscape in *The Cotton Manufacture of Great Britain* (1836) (1: 297-304).
[34] Other guides to specific areas are Edward Baines's *History, Directory, and Gazetteer of the County Palatine of Lancaster* (1836) and Benjamin Love's *Manchester, As it Is* (1839).
[35] This attempt to carefully map the factory system grew, I think, from the possibility, established by William Smith's 1815 geological map of Great Britain, that such a task could be completed and done so accurately. On Smith's map, see Winchester.

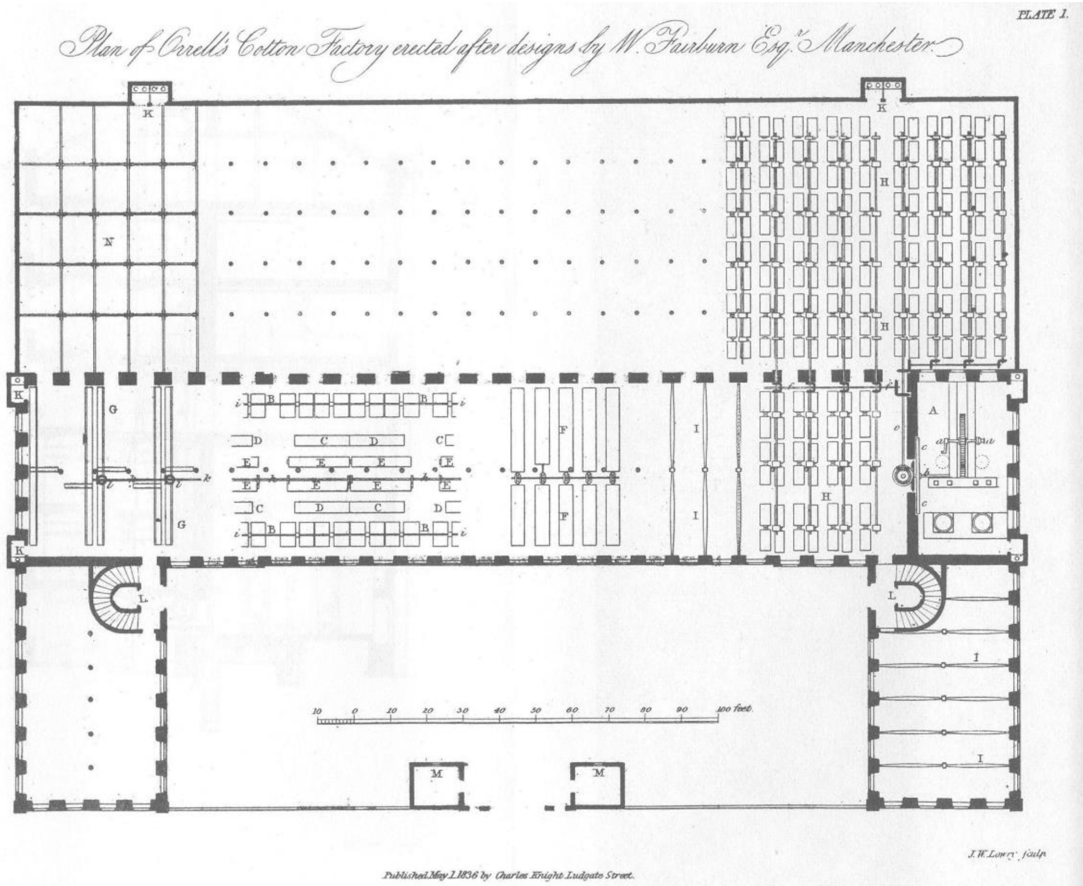

Fig. 3.2. 'Plan of Orrell's Cotton Factory' from Andrew Ure's *Cotton Manufacture of Great Britain* (2: Plate 1).

Associated with mapping and measuring of estates leading to their improvement, the topographic was an empirical vision, objected to by practitioners of the picturesque because it described what was really there (C. Fox 362). In fact, both Ure and Dodd specifically offer a 'topography' of internal factory space, although their explorations of that topography differ.[36] Like writers on the steam engine, they describe the internal 'arrangement' of the factory, a word they both consistently use. Focussing on the ideal factory, Ure's definition of the factory as 'a vast automaton, composed of various mechanical and intellectual organs, acting in uninterrupted concert for the production of a common object, all of them being subordinated to a self-regulated moving force' (*Philosophy* 13-14) makes the factory into a connected train that can be easily diagrammed, mapped, and followed, as in his diagrams of the interior mechanism of Orrell's cotton factory in *Cotton Manufacture* (Figs. 3.2 and 3.3). He takes the reader on a tour of these mechanical processes, in summary in his *Philosophy* and in detail filling the second volume of *Cotton Manufacture*.

[36] Ure, *Philosophy* 44; G. Dodd, *Days* 327.

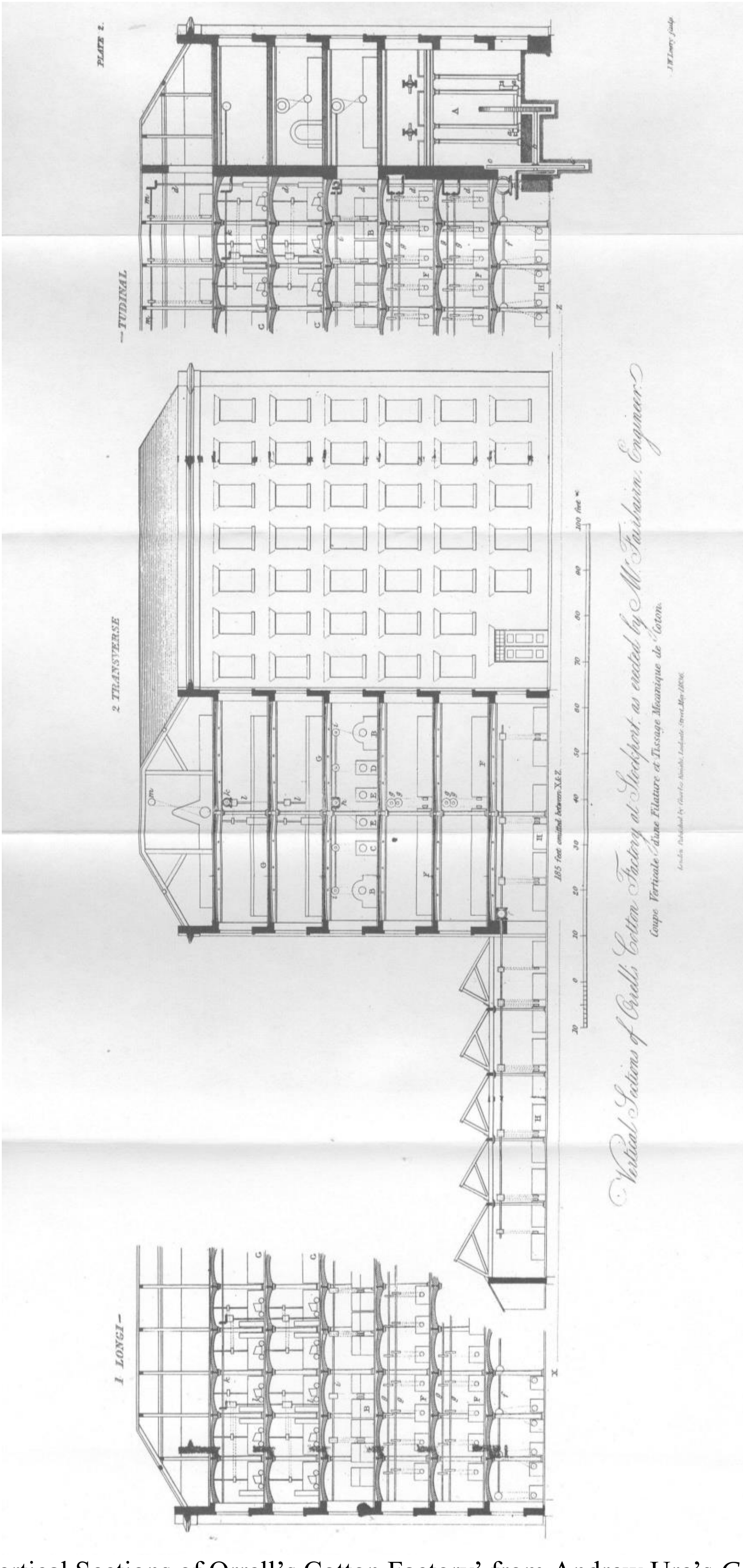

Fig. 3.3. ‘Vertical Sections of Orrell’s Cotton Factory’ from Andrew Ure’s *Cotton Manufacture of Great Britain* (2: Plate 1).

In comparison, Dodd provides a two-part topography: 1) a topography of the factory site and 2) a topography of the manufacturing process. He begins each visit with a description of the site of the factory itself, using the cardinal directions to detail the buildings within the compound and how they relate to each other. He then follows an object through the processes it undergoes on its way to becoming a product, sometimes even mapping them in a diagram (Fig. 3.4). Differing from Ure's insistence on the automatic mechanical connection of each stage, Dodd includes the workman, depending on the physical arrangement of the factory buildings rather than the moving powers to unify the production process. Touring the interior of the factory, Ure and Dodd treat the internal mechanisms and processes with the topographic mode, approaching the interior of the factory as a landscape. By nesting the internal topography within an external topography, they create continuity between the machines inside and the landscape outside the factory.

Writers of factory travel narratives also deployed other modes of seeing the factory which both cemented the factory into the landscape and made it more acceptable as an object of travel. To a culture of tourism organized around the search for picturesque prospects and scenes, whether the factory was worth *looking* at was an open question.[37] In Isaac Taylor's educational narrative for children, *Scenes of Wealth*, the travelling father corrects his children when they do not want to visit manufacturing sites because they are ugly. He acknowledges that the unpleasantness in the factory prospect is something that must be overcome in order to acquire information (10-12).[38] Driving toward Coalbrookdale, he notes that 'the number of furnaces committing out flames and smoke, make a prospect quite new, but not quite pleasant' (97).

While many scholars assume that repulsion was the standard reaction to views of manufacturing landscapes, our travel writers present an entirely different vision, justifying factories through the picturesque visual mode.[39] Ure's ideal factory and its prototypes are consistently located in picturesque spots: Arkwright's mill is 'in the romantic valley of the Derwent' (*Philosophy* 14), Strutt's cotton factory is in a village with 'quite the picturesque air

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[37] On the picturesque and British home tourism, see Andrews.

[38] While I am arguing that the picturesque was enlisted to help represent factories positively, it could also be used to reject the industrial system. In his *Sir Thomas More: or, Colloquies on the Progress and Prospects of Society* (1829), Robert Southey has More ask Montesinos, as they stand looking over into a manufacturing village, 'How is it … that every thing which is connected with manufactures, presents such features of unqualified deformity?' (1: 174). Macaulay sends up Southey's picturesque criteria in his review of the book: he argues that Southey's method to discover the 'principles on which nations are to be governed' is 'To stand on a hill, to look at a cottage and a manufactory, and to see which is the prettier', complaining that Southey makes 'the picturesque the test of political good' (540).

[39] Later, railways were also incorporated into the picturesque, see P. Pacey.

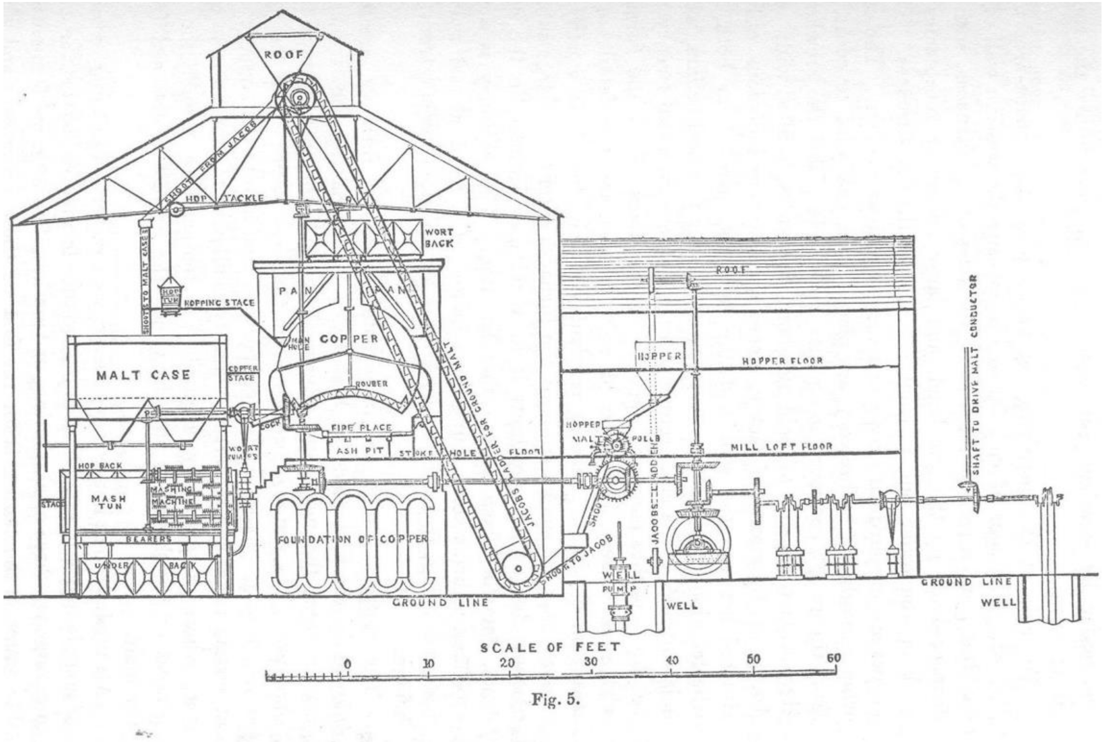

Fig. 3.4. ‘A Day at a Brewery’ from George Dodd’s *Days at the Factories* (25).

of an Italian scene’ (344), the countryside around Greg’s cotton factory in Cheshire ‘is beautiful, and presents a succession of picturesque wooded dells, interspersed with richly cultivated fields’ (346) and Ashton’s mills in Hyde are ‘agreeably grouped together on a gentle declivity’ (349). Indeed, Joseph Wright of Derby even painted the picturesque situation of Arkwright’s mill (Fig. 3.5). Where Ure places his ideal factories in picturesque locales, George Head and William Cooke Taylor consistently *look* at factories through picturesque and romantic modes, although with different emphases.[40] Often highlighting the sublime in the picturesque, Head focuses on his sensations and emotional reactions to looking at industrial scenes, on ‘the impressions received’ by his mind (187). This picturesque is also flexible in Head’s narrative. Manufacturing scenes full of smoke and fire are sublime: ‘to witness a more awful picture, produced by the combined features of fire, smoke, and ashes’ one must go to Etna or Vesuvius (131). But he can also deploy the simple, rural picturesque when looking at quieter manufacturing towns like Matlock or Halifax (117, 124). Cooke Taylor, whose narrative is written ‘in a strongly visual language’ (Gray 134), also employs the technological sublime when he looks at Manchester (1-2), but he falls back on the simpler rural picturesque when describing the ‘good’ factories in the countryside. Writing from Bolton, he enthuses, ‘How a painter would have enjoyed the sight which broke upon my

[40] The picturesque mode of looking at industrial sights is also present in illustrations, as in Edward Baines’s *History of the Cotton Manufacture of Great Britain* (1835).

Fig. 3.5. Joseph Wright of Derby, *Arkwright's Cotton Mills by Night*, Derby Museum and Art Gallery, United Kingdom.

waking eyes this morning', and proceeds to explain the scene: 'the intervening valley is studded with factories and bleach-works. … The smoke too creates no nuisance here—the chimneys are too far apart; and it produced variations in the atmosphere and sky which, to me at least, have a pleasing and picturesque effect' (22).[41] Not only can the factory form an organic part of a picturesque landscape, it can even improve the picturesque-ness of that landscape.

Just as the picturesque mode raised 'the status of British natural scenery and encourage[d] tourism' (Andrews 23), the picturesque mode raised the status of manufacturing

[41] This passage is strongly reminiscent of Wordsworth's description of a rather sanitized Wye Valley in 'Tintern Abbey':

> The day is come when I again repose
> Here, under this dark sycamore, and view
> These plots of cottage-ground, these orchard-tufts,
> Which at this season, with their unripe fruits,
> Are clad in one green hue, and lose themselves
> 'Mid groves and copses. Once again I see
> These hedge-rows, hardly hedge-rows, little lines
> Of sportive wood run wild: these pastoral farms,
> Green to the very door; and wreaths of smoke
> Sent up, in silence, from among the trees! (l.9-18)

scenery by making it part of the celebrated British landscape. Although topographic and picturesque modes of vision are perceived in aesthetic theory as opposites because the former is about empirically recording and mapping the specifics of a location while the latter is about composing a pleasing landscape (C. Fox 362), the genre of factory tourism successfully merged these modes in defence of the factory system. The topography of the factory system located factories in a real rather than imagined geography, while the picturesque made that geography a specifically picturesque one, justifying factory tourism by making the factory worth seeing. The picturesque was not just beautiful, but it was also natural, usually integrating man-made things into a natural landscape. Fusing the topographic and the picturesque, factory tourism narratives presented a morally acceptable factory system by integrating it with a specific and natural landscape.[42]

While Head, Cooke Taylor, and Dodd were limited by the travel narrative genre to describing *where* factories are, Ure explained *why* they are where they are in his systematization of industrial knowledge. He made the placement of factories in the countryside natural and necessary through his 'Topography' of the factory system. Although I have identified a topographic mode of looking at and describing the factory in these travel narratives, Ure himself, taking textile manufacturing as his example, defines factory 'Topography' in *Philosophy* as 'the causes why one district is occupied chiefly with cotton fabrics, a second with flax, a third with wool, and a fourth with silk' (67), or, as he says in *Cotton Manufacture*, 'why manufactures flourish more in one district than another' and why different textiles have 'their favourite localities' (1: xi; 2: 423). In *Cotton Manufacture*, Ure expands this concern to a global level: why does England have international industrial supremacy? Why is the most advanced factory system located in England, rather than in France or India or America? His answer, both on domestic and international levels, is simple: natural resources. Factories emerge around the necessary natural resources, both for power and for the raw materials of production. Joining contemporaries, Ure includes both the 'natural resources in fire and water power' to explain why cotton manufacturing thrived in Lancashire, Lanarkshire, and Renfrewshire.[43] But in his selective and idealistic vision, Ure focuses almost entirely on factories that depend on water, rather than coal and steam, for power. As Baines observed in his *History of the Cotton Manufacture of Great Britain* (1835),

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[42] The picturesque visual mode can also manifest in the technological sublime, working against the comprehensibility of machines discussed in chapter 2. Although it threatened the machine's comprehensibility, 'the aesthetic determinant of the prospect, strengthened by picturesque considerations, ensured that the main manufacturing cities were viewed from a distance with moral approbation' (C. Fox 392).
[43] *Philosophy* 67-68. See also Baines I.113; James 585-640.

steam engines meant that factories could move into towns (227), a move our peripatetic factory defenders either ignore or disapprove. Succumbing to 'the nostalgic appeal of water power' (Ketabgian 112), Ure prefers water wheels to steam engines when possible (*Philosophy* 346), while largely ignoring the moving power of the factories. So he continues to imagine and locate the factory system within specific topographies in the landscape, connected necessarily to the natural resources they offer. Since the necessary streams of water with the necessary drops are in picturesque locations, at the bottoms of picturesque little valleys, the factory system he presents and idealizes is in those valleys.[44] Thus Ure naturalizes these picturesque localizations: factories are where the natural resources of coal, water, and iron are to be found. Their positions in the British landscape are not arbitrary but natural.

So far then, the topographic mode of industrial tour narratives inscribed the factory system and internal factory space into the real landscape of England. Then the picturesque mode put them in a beautiful natural setting. Finally, Ure's 'Topography of the Factory System' implied that factories necessarily emerged in picturesque locations because of the necessary natural resources. Indeed, Ure delights: 'how completely the marts of industry are the offspring of nature' (*Cotton* 1: 187).

Ure does not stop with asserting that factories are where they are because of natural resources; he turns factories themselves into natural resources by naturalizing his factory topography through a series of organic metaphors for factories, industry, and machines. Perhaps the most common—and commonly remarked—is Ure's 'anatomy of the mill' (*Philosophy* 34) in which the mill is an animal body composed of various organs.[45] But Ure also proposes other organic metaphors:

> Could a metaphor have proved anything, a more appropriate one might have been found, in the process of vegetable and animal generation, to illustrate the great truth, that Providence has assigned to man the glorious function of vastly improving the productions of nature by judicious culture…. (278)

[44] When he does discuss factories using steam engines, he focuses on steam as a natural element, rather than on the machines that produce it, making the working of the factory an extension of natural powers and processes.

[45] *Philosophy* 32, 34, 55. Although serving an explanatory purpose, this metaphor engages and renovates contemporary political and sociological discourse in which society was presented as a body and on which the factory system was sometimes presented as a cancerous growth. On Ure's body metaphors, see Bizup 18-51; Ketabgian 19-26. On body metaphors for society in nineteenth-century Britain, see Poovey, *Making* 74-88. Southey famously presented the factory system as a cancer in his *Colloquies* (1829): 'It is a wen, a fungous excrescence from the body politic: the growth might have been checked if the consequences had been apprehended in time; but now it has acquired so great a bulk, its nerves have branched so widely, and the vessels of the tumour are so inosculated into some of the principal veins and arteries of the natural system, that to remove it by absorption is impossible, and excision would be fatal' (Southey 1: 171).

Although he does not often reflect on his choice of metaphors, Ure does utilize and expand the two he mentions here, drawing on 'the process of vegetable and animal generation' to present the factory system positively. He develops the plant growth metaphor in *Philosophy* and the animal birth metaphor in *Cotton Manufacture*, each engaging larger discussions or implicitly addressing larger questions about the impact and value of manufacturing.[46]

Seeing the factory system as 'the offspring of nature' (*Cotton* 1: 187), Ure consistently presents manufacturing industry as a plant in *Philosophy*.[47] Not only using topographic and picturesque techniques to understand machines, he also uses the very forms of nature to present machines. Although he was not the only one to use the plant metaphor, it took on special significance in the context of his fascination with the textile industry, especially with cotton. While he claims to write about the factory system generally, Ure focuses solely on textile manufacturing, an industry in which the transformation from raw material through mechanical processes and on to finished product is easily encompassed in explanation. Ure naturalizes this continuity between the raw materials and the factory by making the success of industry depend on the natural environment, especially the weather, for the growth of the raw materials.[48] Eliding the various phases of cotton manufacturing, Ure portrays the factory system as vulnerable to the weather like plants are. Ure's *Cotton Manufacture* pulls the threads of this connection even tighter: 'The object of this work is to describe cotton in its various forms, from the development of its filaments in the seed-vessel of the plant, through their several mechanical combinations, till they compose a web of exquisite beauty' (1: 1). The ambiguity of the final phrase suggests both that the final cotton cloth is a 'web of exquisite beauty' and that cotton's natural qualities combined with the machines that process them form this exquisite web. Implicitly supporting the plant metaphor, Ure begins *Cotton Manufacture*, his explanation of the entire industry including its machines, with an explanation of cotton as a plant. He glides smoothly from describing the cotton plant to describing factory processes and machines, implying their similarity and hiding their incongruence. Understanding cotton scientifically as a plant and understanding the factory system metaphorically as a plant, he merges them into one natural resource and product.[49]

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[46]The birth metaphor was fairly common in pro-industrial rhetoric like Edward Baines's *The History of the Cotton Manufacture* (1835), James White's *A New Century of Inventions* (1822), and Alex Johnston Warden's *The Linen Trade* (1864).
[47] Ure, *Philosophy* 16-17, 42-41, 255, 435, 446.
[48] Ure, *Philosophy* 128, 130, 237.
[49] By presenting factories as almost agricultural products of England, Ure and Babbage daringly replace agriculture with manufacturing as the driving force of British commerce (Zimmerman). The plant metaphors

Ure's representation of the factory system as a plant naturalized the factory's place in the landscape, as the factory was metaphorically rooted in and growing out of England's land. Ure reinforces this connection through a metaphor drawn from the land itself: he consistently refers to the 'stream' or 'river' of labour and capital, naturalizing the human sources of the factory system. Although he does not say so explicitly, this metaphor suggests that the factory plant is watered by capital and labour. Merging with the plant metaphor, the river metaphor reinforces the literal placement of factories in picturesque valleys through which actual rivers runs. Ure deploys the river metaphor against government intervention in economics, as a river forced out of its natural bed will cause significant damage to the surrounding countryside or to the stream itself.[50] Industry flows in a natural steam which finds its own equilibrium, the image rewriting Adam Smith's invisible hand. Taken together the plant and river metaphors ensure that the factory system is not a blight on the landscape, but an organic part of it rooted in a specific topography. While Ure's focus on topography makes his organic metaphors more tenable, especially in their relevance to external social questions, his organic metaphors also reinforce, although not logically, the naturalization of his topography of the factory system. Indeed, Ure's consistent use of organic and natural metaphors for machines reverses the application of mechanical metaphors to nature, re-establishing the similarity of nature and machines.

Naturalizing the Mechanical: Taxonomy, Natural History, and Technology

With manifold cultural implications, travel served multiple functions in popular technology's naturalization of the factory system. While popular technology texts used topographic and picturesque ways of seeing and experiencing the landscape in order to represent and justify factories, they also exploited travel's association with discovering knowledge about the order of nature, particularly in natural history, to construct technology as part of that order. The genre follows a larger pattern in the production of scientific knowledge from the seventeenth to the nineteenth centuries: it was often produced through travel. Likewise, Babbage's *On the Economy of Machinery and Manufactures* and Ure's *Philosophy of Manufactures* present knowledge of machines as the empirical product of first-hand experience acquired through visiting factories. They then borrow the taxonomic system

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also engage with the core of contemporary class and political struggles between the landed, agrarian, upper class and the emerging, industrial middle class. They hijack a discourse which aligns agrarian wealth with British national identity and which excludes industrial wealth as somehow foreign to what is naturally British.

[50] Ure, *Philosophy* 17, 41, 69, 107, 280, 459.

from natural history to organize mechanical knowledge, ultimately merging machines and nature into the same system.

Before being adopted by Ure and Babbage, natural history, or the system of organizing knowledge of nature, was the offspring of travel. Commercially and colonially motivated voyages of discovery in the Renaissance brought back specimens and information about the quality and distribution of natural resources around the world.[51] The specimens and artefacts then became collector's items. In turn, these sometimes huge collections needed to be organized and catalogued, inducing the pursuit of a rational classification system. Thus natural history, particularly taxonomy, was born in the pursuit of the collection, naming, and arrangement of every natural object—animal, vegetable, and mineral. Today, classification is understood as '*a spatial, temporal, or spatio-temporal segmentation of the world*. A "classification system" is a set of boxes (metaphorical or literal) in which things can be put to then do some kind of work—bureaucratic or knowledge production' (Bowker and Star 10). Thus classification is structured by a spatial metaphor: all specimens or bits of knowledge are organized conceptually as if they could be fit into separate boxes that have specific spatial relationships to each other. Taxonomy then maps these boxes and their relationships. This spatial metaphor connects travel and classification with an even deeper bond: knowledge is a landscape that needs to be mapped, making taxonomy into a topography of knowledge and of the order of nature. Indeed, through taxonomy, naturalists sought to map the underlying system of nature, and the laws governing its order.[52]

As the study of natural history grew, it motivated and shaped travel. If natural history was a system for knowing nature, then travel was a practice for knowing nature in this period. In the late eighteenth century, naturalists like Joseph Banks fanned out across the globe trying to fill in the gaps of the classificatory system set out by Carl Linnaeus.[53] In the early nineteenth century, fieldwork became natural history's 'primary practice' (Endersby 17). While this field was often overseas, as for Charles Darwin, it could also be local: every man could move through the natural landscape collecting information about a small environment and the natural objects within it.[54] Premised on the simple collection and description of specimens that would fit into a pre-ordered structure of knowledge provided by the great

[51] Hulme and Youngs 4.
[52] On the history of natural history, see Farber; and the essays in Jardine, Secord, and Spary. On the relationship of natural history and travel, see the essays in Miller and Reill. For a history of the naturalist in Britain, see Allen.
[53] Hodacs.
[54] For Victorian fieldwork, see Endersby 31-53; for international fieldwork, see Raby; and for local geological fieldwork and for the importance of local natural history field clubs, see Allen 45-49, 142-157.

naturalists like Ray, Linnaeus, or Buffon, natural history was open to any person who could move around the countryside in nineteenth-century Britain.[55]

While industrial travel narratives mapped factories onto Britain's physical landscape, many of these narratives also integrated factories into the abstract order of nature by borrowing the concerns and methods of natural history to understand machines. For them, industrial tourism was an extension of natural historical tourism: its purpose was the empirical collection of data about and the classification of machines, working toward the systematization of technological knowledge and its integration with science—the study of nature. Some, like Head and Cooke Taylor, were more concerned with how factories looked, than with their species and classes. Yet they took the first step in the classification and organization of knowledge through the collection and organized reporting of information.[56] Other texts made classification central to their work.

Concerned throughout his career with how to classify manufactures, George Dodd recognized the difficulty of this project:

> It is generally found, when an attempt is made to classify manufactures with any strictness, that the difficulty of deciding on the contents of each group becomes more and more felt as the classification advances. This arises from the circumstance that each complete occupation, or chain of processes, may be regarded in many points of view, giving rise to as many modes of grouping as there are phases of character. (*British* 5)

As in nineteenth-century natural history, the question was not whether there was order but on what principles that order rested—on how to organize the technological taxonomy. Dodd roughly divided factories by the products they made, but this was not good enough for Ure and Babbage.[57] They sought to systematize mechanical knowledge, beginning this project in *The Philosophy of Manufactures* and *On the Economy of Machinery and Manufactures*. Their titles gesture towards their goals: at this time, what we call 'science' was called

[55] Mimicking the peripatetic practices of natural history, Victorian popular science texts sometimes deployed the travel narrative form, allowing the home-bound reader a 'participatory experience of nature' (Lightman, *Victorian* 49), as in Hugh Miller's *The Old Red Sandstone; or, New Walks in an Old Field* (1841), Charles Alexander Johns's *Botanical Rambles* (1846) (Lightman, *Victorian* 48-52), Charles Kingsley's *Glaucus, or Wonders of the Sea Shore* (1855), G.H. Lewes's *Seaside Studies* (1858), and W. Houghton's *Country Walks of a Naturalist with His Children* (1869).

[56] The very act of explanatory or descriptive writing, including travel writing, implicitly involves organizing knowledge, see Viviès 111.

[57] Head and Cooke Taylor organize their narratives by place. Other non-travel treatments of industry are organized around products, raw materials, or a combination of both: Isaac Taylor's *Scenes of Wealth* (1826) is organized by product; *Minerals and Metals; their Natural History and Uses in the Arts* (1835) and John Holland's *A Treatise on the Progressive Improvement and Present State of the Manufactures in Metal* (1831-33) by material; and Arthur Aikin's *Illustrations of Arts and Manufactures* (1841) by both.

'philosophy' while 'economy' signalled that Babbage's work intervened in the 'dismal science' of political economy, which tried to build systematic, empirical, and mathematical knowledge about the way value circulated. Seeking to establish a popular science of machines, Babbage and Ure both turned to classification as their scientific method, rather than to the more theoretical and complex approaches of physics or mechanics.

The natural history Babbage and Ure extended to machines was not a static discipline, but one with varying and developing concerns which they reflected. Its methodologies were laid out in the mid-eighteenth century through the contrasting approaches of Carl Linnaeus in Sweden and Georges-Louis Leclerc, Comte de Buffon, in France. Linnaeus emphasized detail. He championed the collection and naming of specimens that could be slotted into his classificatory scheme. Buffon emphasized system. He collected and organized the natural products available to him into a comprehensive structure in his 36-volume *Histoire Naturelle* (1749-1788). Subsequent natural history was informed by and combined the two. Around 1800, the branches of natural history began to diverge. While botany and geology remained strong, zoology and its methodologies became predominant. Although Linnaean collecting of quotidian specimens remained important to British botany, zoology was more concerned with how different species related to each other in the order of nature and with how to distinguish classes. As zoological natural history developed, comparative anatomy became the key to classification and to discovering nature's order. Here also came methodological divergence. In France, Georges Cuvier focused on an organism's function, suggesting that its structure was determined both by the functional relationships between internal parts of the body, or the 'correlation of parts', and by the external functional relationships of an animal to its environment, broadly construed. Another Frenchman, Etienne Geoffrey Saint-Hilaire focused on form rather than function, looking for the 'blueprint' (Farber 38) of all vertebrates which would explain the similarity between the anatomical architectures of different animals. In the 1840s, Richard Owen took Saint-Hilaire's position even further, focusing on pure form without function to posit structural 'archetypes' as the key to classification. Yet the focus on function ultimately triumphed. But as the century progressed, physiology emerged as an alternative to natural history. Sheering science of the pursuit of an overarching order of nature, physiology primarily studied how things functioned, focussing on the functional processes of organisms, organs, and systems, while losing interest in universal classification.

Whether specifically elaborating a taxonomy of machines or merely applying the nomenclature of 'class' and 'species' to machines and factories throughout their work, Babbage's *Economy* and Ure's *Philosophy* internalized the methodologies and emphases of their contemporary natural history, making function the principle of classification.[58] While texts on the steam engine took the first step in a science of machines by naming machines and their parts, Babbage continues this process by carefully distinguishing between tools and machines (*Economy* 12). He then classifies machines by purpose into two classes (16): ones that produce power and ones that transmit force or execute work (16-19). As with standard natural history, Babbage sees this division as inherent in 'nature' (16), rather than as an artificial distinction created by his own mind. Carefully tending this graft of machines onto nature's order, he observes that machines do not create power. Instead, machines merely convert sources of power which already exist in nature or accelerate what is already done in nature (17-18, 40). Assuming the continuity of nature and machines, Babbage does not apologize for his application of natural historical methods to machines. Like many naturalists, Babbage has his favourite species: mechanical processes for copying, which he sees as the source of manufacturing excellence and the cheapness of products (69). He gives an extensive, although incomplete, list of the 'processes' or 'operations' of copying (69-70), which he divides into six categories and then into further sub-categories (69-113). Taking a single variety of factory, Babbage classifies its sub-types according to how they work. Yet Babbage's focus on function is not subsumed in a comparative anatomy of different factories; he does not actually describe and compare the parts of factories. Although he uses function to classify, his natural history of machines slides toward a physiology of machines in its focus on a single variety, reflecting his specific intellectual context.

While classification is a relatively limited part of Babbage's eclectic analysis of machines and manufactures, it plays a much larger role in Ure's *Philosophy of Manufactures*. A standard pillar of science, classification is structurally integral to Ure's science of machines.[59] *Philosophy* begins with a definition of 'manufactures', then proceeds to categorize factories first by their processes, either chemical or mechanical, and then by whether they work on animal, vegetable, or mineral materials (1-2). Like Babbage, Ure has a favourite species: the mechanical operations on vegetable and animal fibres because he sees in them the achievement of perfect automation (2-3). After classifying the types of natural fibres, he identifies 'five distinct classes of factories' which 'all possess certain family features' in the functions of their parts (2-3). Returning to the classification of factories later in the work, Ure gives special attention to the principles of division. He lays out two options: factories can be classified by their subjects as in natural history or by their actions on these

[58] On Babbage and Ure's technological 'taxonomy', see Bizup 53; Gray 133.
[59] For Ure's goal of making a science of machines, see Gray 133.

subjects (56-57). For Ure, ‘the true philosophical principle of classifying the mechanical manufactures’ (56-57) is the way they work on matter, which Ure lists and describes (57-63). But he also goes inside the factory, to classify its component machines by their functions: to produce power, to transmit or regulate power, or to apply power to modifying materials (3). Indeed Ure sees machines as functional units within the ‘anatomy of the mill’ (34).

Surprisingly similar taxonomies because based on function, the taxonomies of Ure and Babbage reflect different strains of early nineteenth-century natural history. Babbage’s taxonomies border on physiology because of their focus on function without elaborated comparisons between types. By contrast, Ure’s *Philosophy* is a full-on comparative anatomy of factories organized around function rather than form. Not only does Ure identify the classes of a mechanical taxonomy, but also describes each of his five classes of textile factory in Book II (81-276). Devoting a chapter to each type, he dissects each factory and describes its major functional parts, allowing the reader to compare their internal architectures. His *Cotton Manufacture of Great Britain* takes this one step further by devoting its entire second volume to the description and dissection of the anatomy of one type of factory. Deeply concerned with getting the classification of vegetable cotton right (1: 56-95), Ure blends an implicit mechanical taxonomy with the natural history of cotton. Yet his focus on function in *Philosophy* gives way to a focus on form in *Cotton*, where he describes a single, ideal factory rather than actual ones. Without the comparative format, Ure leans toward the contemporary ‘blueprint’ or ‘archetype’ natural histories of Saint-Hilaire and Owen. In a broader view, however, both are trying to answer larger, Cuvierian questions. Interested in the internal ‘correlation of parts’ by function, they try to discover how the factory relates to and functions within its commercial, social, national, and moral environment.

Ure’s metaphors for the factory system register his resonance with contemporary natural history while they also naturalize his taxonomy. His metaphors are animal (anatomy, birth), vegetable (plant), and mineral (river), but he comes back to the animal most frequently, seeing the factory as an animal anatomy with machines for organs. Indeed, for Ure the ‘engines of the cotton trade’ are ‘a series of organs, instinct with intellectual purpose’ and which, ‘in complexity, as well as perfection of organization, … surpass all others, just as the human body does a zoophyte’ (*Cotton* 1: xcvii).

As with topography, these taxonomies of machines wrote machines into nature. While topography engraved factories into the natural landscape, taxonomy incorporated machines into the order of nature. Naming, classifying, and comparing, these texts reveal pattern, structure, and order in the forms and functions of technology. By using techniques and categories borrowed from contemporary natural history, they merge machines with the object of natural history: nature. Yet topography and taxonomy are not distinct practices or approaches to nature. Historically, travel produced the need for taxonomy while the drive to a complete classification system both motivated travel and depended on topographic practices of mapping to collect data. Tangled together in the study of nature within the framework of 'natural philosophy', taxonomy and topography make the same assumption about nature: nature and scientific truth are *out there* to discover. The human mind merely discovers that order. The topographer records that order in his geographical charts while the taxonomer records that order in his taxonomic charts. In the same way, the mapping of industrial topography fused with the mapping of the taxonomy of machines. This fusion of epistemological techniques reinforced the naturalness of machines by replicating the structures and techniques of knowing and appreciating nature. Separately, topography and taxonomy identified similarities between machines and nature; but together they present machines as fully participant in nature and in its God-given order which was out there to discover.

Yet, contrary to the beliefs of their nineteenth-century practitioners, the techniques of taxonomy and topography did not discover scientific truth or that machines participated in nature's order. Rather, they produced it. In *Technologies of the Picturesque*, Broglio has suggested that the techniques for looking at nature transform the natural 'thing' into an 'object' with 'a halo of social meaning' (15-16). Such methods 'ideologically constitute what they claim to measure' (19). These techniques are not necessarily physical things, but are also methodologies, discourses, and practices. As methods for looking at nature, taxonomy and topography turn nature from a thing into a meaningful object, the meaning provided as much by the technique as by the object to which it is applied. When the same techniques are applied to the machine, they transform it into an object with a similar 'halo of social meaning' to nature's, for the locus of meaning is as much in the way of looking as in the object. Because constituted by the same techniques, machines and nature share meanings. Thus nature and machines were not essentially distinct; they were part of a network of meanings woven by the technologies of taxonomy and topography. By borrowing approaches from the study of nature, Ure, Babbage, and the industrial travel writers naturalized machines, guaranteeing the similarity necessary for natural theology.

A Symbiosis of Natural Theology and Popular Technology

Accomplished by applying lenses to machines which were usually applied to nature, the blurring of the mechanical and the natural achieved by Babbage, Ure, and other industrial travellers generated multiple cultural effects. As Bizup has observed, the 'naturalization of the factory system' served to 'deflect and subvert' anti-industrial rhetoric focused on the conditions of workers, although it could not entirely overcome it (37-38). While these texts specifically answered the charge that the factory is unnatural, they failed to defeat anti-industrial rhetoric because they focused on machines as objects rather than the quality of the labour required within them. But this 'naturalization' also helps to explain the continued plausibility of the design argument, shown by the popularity of the Bridgewater Treatises, both authorized and unauthorized, and of Brougham's *Natural Theology* in the 1830s. Implicitly answering Hume's objection to the design analogy—that machines and nature are not alike—these popular technology texts maintained the design analogy's plausibility by reinforcing the aptness of the analogy: machines are like nature, or maybe even part of nature. As the overt mechanization of nature faded from science, popular technology took up the burden by naturalizing the machine. Even while the Bridgewater Treatises do not use mechanical metaphors as overtly or as often as Paley did three decades previously, they draw on a system which projects the qualities of machines onto nature and the qualities of nature onto machines. Thus my penultimate conclusion is that these texts of popular technology enabled the natural theology of the 1830s by supporting one of the assumptions and intuitions on which design depends—the similarity of nature and machines.[60]

But there is also more to the story. This formulation locks the relationship between the two sets of texts into one of mechanical cause-and-effect.[61] When other types of relationship are allowed, a fuller picture emerges. The relationship between the two sets of texts can also be understood organically as a symbiotic relationship of interconnection and exchange established through the contact points of topography and taxonomy. Circularly, popular technology enabled natural theology which enabled popular technology. Through the deployment of the same representational techniques of topography and taxonomy, natural theology and popular technology became mutually beneficial practices.

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[60] In contrast to my approach, Brooke and Cantor have explored the problems that might arise for natural theology when the natural and artificial are blurred (314-346).

[61] This was largely the approach I took in chapter 2.

One contact point in the symbiosis of these seemingly irrelevant genres is the meaning of the natural landscape and how that meaning was constituted by topographic and picturesque visual modes. In the nineteenth century, natural theology, especially when focused on the earth sciences, revealed a landscape glowing with evidence of God's providential care for mankind. When factories were integrated into that landscape, they also became part of the beneficial world humans inhabited. But that integration also solved one of the major challenges to the design argument: what about when God or nature fails to deliver on their benevolent promises?

In England, 'science' emerged in a religious climate which understood nature as made for man by a benevolent deity.[62] The very qualities of the English landscape fostered this confidence in nature's benignity and thus the growth of natural theology: there are no volcanoes, earthquakes, large predatory animals, or tsunamis in Britain. It is temperate and fertile with a relatively gentle topography. Food is easily grown or gleaned. This nature ready-made for man's benefit played a large, although relatively unexplored, part in the special relationship of science and religion in England.[63] As science developed, modes of *looking* at the landscape developed which both assumed and reiterated the landscape's benefit to man: the topographic and the picturesque.[64] Concerned with mapping and describing the features and resources of a specific piece of land, topography highlighted the useful parts of the landscape while subtly constructing nature as orderly.[65] The picturesque presented a landscape that was beautiful, playing into the Paleyan emphasis on the pleasure God intended for man and giving a function to otherwise non-useful landscapes, like mountains.[66] Not only did these modes of seeing the natural landscape generally support the conviction of a benevolent designer of nature, they also promoted the development of sciences that would reveal benevolent intentions in nature. The practices of practical topography interested in mapping the useful mineral and agricultural landscape developed into the science of geology,

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[62] For anthropocentrism in English scientific thought through the nineteenth century, especially in natural theology, see Brooke, '"Wise"'.
[63] Brooke, 'Why' 62-63. A full 'geography of knowledge' study of natural theology in England remains to be done. It is possible that design as a conceptual metaphor had a special place in Britain because of the qualities of the landscape. On the role physical environment has to play in the formation of conceptual metaphors, see Kövecses, *Culture* 232-233.
[64] For the importance of vision and seeing rightly to natural theology, see Lightman, 'Visual'.
[65] For the practices and meaning of topography, see C. Fox 46-132, 362-444. For how surveying technologies created the landscape's meaning, see Broglio.
[66] For beauty negotiating between science and religion, particularly in natural theology, see Brooke and Cantor 207-243. For the interaction between visual images and text in later natural theology, see J. Smith, 'Philip'. In the late nineteenth century, James Houghton Kennedy developed a natural theology from the human perception of beauty (Kennedy 137-194). The picturesque and the sublime were also often worked into theologies of nature, that understood nature from within a theological context, often transferring wonder at the beauty and power of the universe onto God, see Astore; Brooke and Hooykaas 1-54; Fyfe, 'Science'.

while the picturesque made geology an attractive study involving travelling through and looking at natural features.[67] Indeed, the 1843 edition of Wordsworth's *Guide to the Lakes* brought the topographic and the picturesque together, including letters by Adam Sedgwick on the geology of the Lake District.

Although historical sciences eventually complicated natural theology, geology was easily integrated into it in the 1830s as the science of landscape which revealed the adaptation of the earth to the good of humans.[68] Although many of its authors mitigated the strong anthropocentrism of the Baconian vision, the original conception of the Bridgewater project still assumed a kind of human-centeredness by focusing on God's characteristics of wisdom, benevolence, and power. What better way to show God's benevolence than by demonstrating how nature benefited man? Indeed, the treatises by Chalmers and Kidd focus on the 'Adaptation of External Nature' to the mind and to the body of man, respectively. While Chalmers takes 'adaptation' as the adjustment of external and internal to each other, Kidd is concerned very specifically with man's 'empire over the external world' (28) and with how nature—animal, vegetable, mineral, and atmospherical—serves humanity's good. He describes both the atmosphere (80-151) and minerals (152-201), including the 'Geological Arrangement and physical Character of Some of the superficial Strata of the Earth' (173), as evidences of obvious adaptation to human needs.

Where Kidd discusses nature generally, other authors consider specific scientific areas. Of those concerned with earth sciences, Whewell discusses astronomy and the nature of the earth, Prout meteorology, and Buckland geology. Although asked to discuss astronomy, Whewell found 'Terrestrial Adaptations' (*Astronomy* 1-147) to be more powerful instances of design because they can be seen and because they benefit animate beings (16). Showing how the organic and inorganic phenomena are fine-tuned to each other, Whewell considers the lengths of the day and the year, the mass of the earth, the size of oceans and atmospheres, and the distribution of climates. Although he sees 'adaptation' as fine-tuning rather than service of man's good necessarily, he gives man a special place in a universe directed by Providence (279-293, 282).[69] Prout offers a more detailed explanation of meteorology and climate according to chemical rather than physical laws, highlighting how climate and its matching organic beings reflect God's character, particularly his wisdom. Finally, Buckland's

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[67] On topography and geology, see Rudwick, *Bursting*, 'Minerals' 271-273. On the picturesque and geology, see Allen 46-47.

[68] On geology as challenge, see Gillispie; Klaver. On geology's integration, see Brooke, 'Natural Theology of the Geologists'.

[69] Whewell finds a philosophical protégé in one of today's leading natural theologians: Alister McGrath. This is evident in the final chapter of *Darwinism and the Divine* (2011) and *in A Fine-Tuned Universe* (2009).

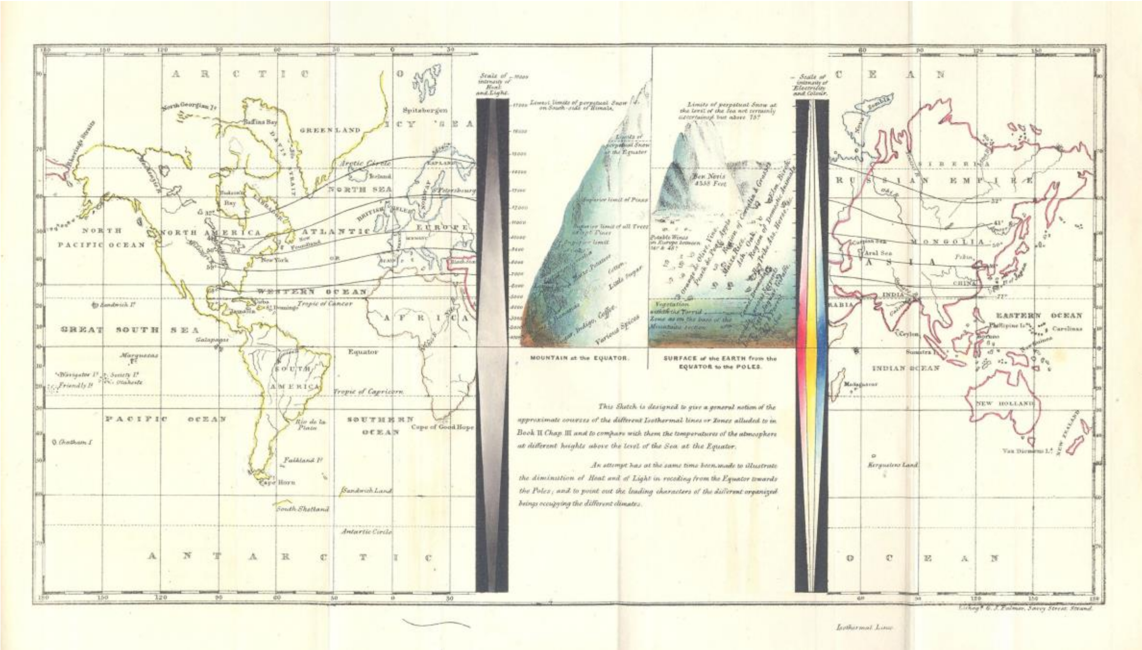

Fig. 3.6. Diagram of the earth's isothermal lines from the third edition of William Prout's *Chemistry, Meteorology, and the Function of Digestion* (opposite 510) but originally from Prout's 'Meteorology' in the *Encyclopaedia Metropolitana*.

Incredibly popular treatise on geology actually begins with a hypothetical situation in which three travellers tramp across different areas of Great Britain and come to wildly different conclusions about its landscape (1: 1-3). Before turning to contrivances in fossils, Buckland discusses geography and the distribution of minerals in the earth's crust, noticing how they have been placed, at least in England, where man can easily access them. Growing out of the topographic tradition, these earth scientists are concerned with the distributions of populations, climates, and minerals, connecting them to the beneficial intentions of Providence. The importance of seeing these distributions is emphasized by Prout who maps the earth's climate zones (Fig. 3.6) and by Buckland who provides a detailed diagram of different geological strata (Fig. 3.7) and fills his second volume with illustrations of the first. Employing the techniques of topography, earth science natural theologies represent the human-benefiting landscape as evidence of God's goodness.

This natural theological tradition, grafted onto the British passion for nature, painted the landscape as Providentially beneficial to man. Not only was it beautiful, but it was useful too. In their naturalization of machines, Ure and the other industrial travel writers capitalized on these meanings of the landscape. Integrated into it, the factory took on the landscape's qualities, becoming beneficial to man—and part of Providential intention. Yet popular technology did not merely steal the fine garments of Providential benefit to clothe industry: the natural theological tradition prepared for the merging of factories into a Providential landscape. Although the Bridgewater authors soften the anthropocentrism of Bacon, they often still present nature as particularly suited to humanity's arts and industry.[70] While excluding discussion of it, Whewell recognizes that the physical laws of nature are useful to human arts (*Astronomy* 113). For Buckland, coal's qualities, its location, and its distribution in the earth's crust are adapted to the works of man (1: 524-538). Prout perhaps states this adaptation of the physical world to the arts of man the most strongly:

> what a splendid evidence of design and of preconcerted arrangement on the part of the great Creator is thus exhibited, by viewing the inherent properties of matter, and its various conditions, with reference to the works of man. Had water, for instance, not been constituted as it is, man could never have formed the steam engine. Had not the productions of the temperate climates been formed with that capability for change, by which they are so much distinguished, man could never have so moulded them to his uses, by altering their character. There was no reason why such properties should have been communicated; there was even no reason why the objects in which these properties exist, should have been created. But they have been so created; and what are we to infer? No one surely will contend that they have been the result of chance, or have been created without an object. (410)

Yet the incorporation of the factory into the Providential landscape did more than justify the factory system. Merging factories with the natural landscape, authors of both popular technology and natural theology saw the factory as a completion of nature—as a Providentially prepared solution to the problem of pain.[71] Much has been made in the Christian tradition of the expulsion of man from the Garden of Eden and the resulting curse on humanity: 'cursed is the ground for thy sake; in sorrow shalt thou eat of it all the days of thy life; Thorns also and thistles shall it bring forth to thee; and thou shalt eat the herb of the field; In the sweat of thy face shalt thou eat bread, till thou return unto the ground' (*KJV*, Gen. 3.17-19). Because nature fell with man, God's direct provision for mankind's good is no longer brought to completion. Many in the Christian tradition, including Francis Bacon, believed that this curse could be relieved through the work of man himself using what was

[70] For example, William Buckland is 'unwilling to press the theory of relation to the human race, so far as to contend that all the great geological phenomena we have been considering were conducted *solely* and *exclusively* with a view to the benefit of man. We may rather count the advantages he derives from them as incidental and residuary consequences; which, although they may not have formed the exclusive object of creation, were all foreseen and comprehended in the plans of the Great Architect of that Globe' (1: 99).

[71] Otherwise known as the problem of evil, this challenge far predated evolution's emphasis on pain and death in nature, although Darwin added his own nuance to the discussion, see McGrath 166-171.

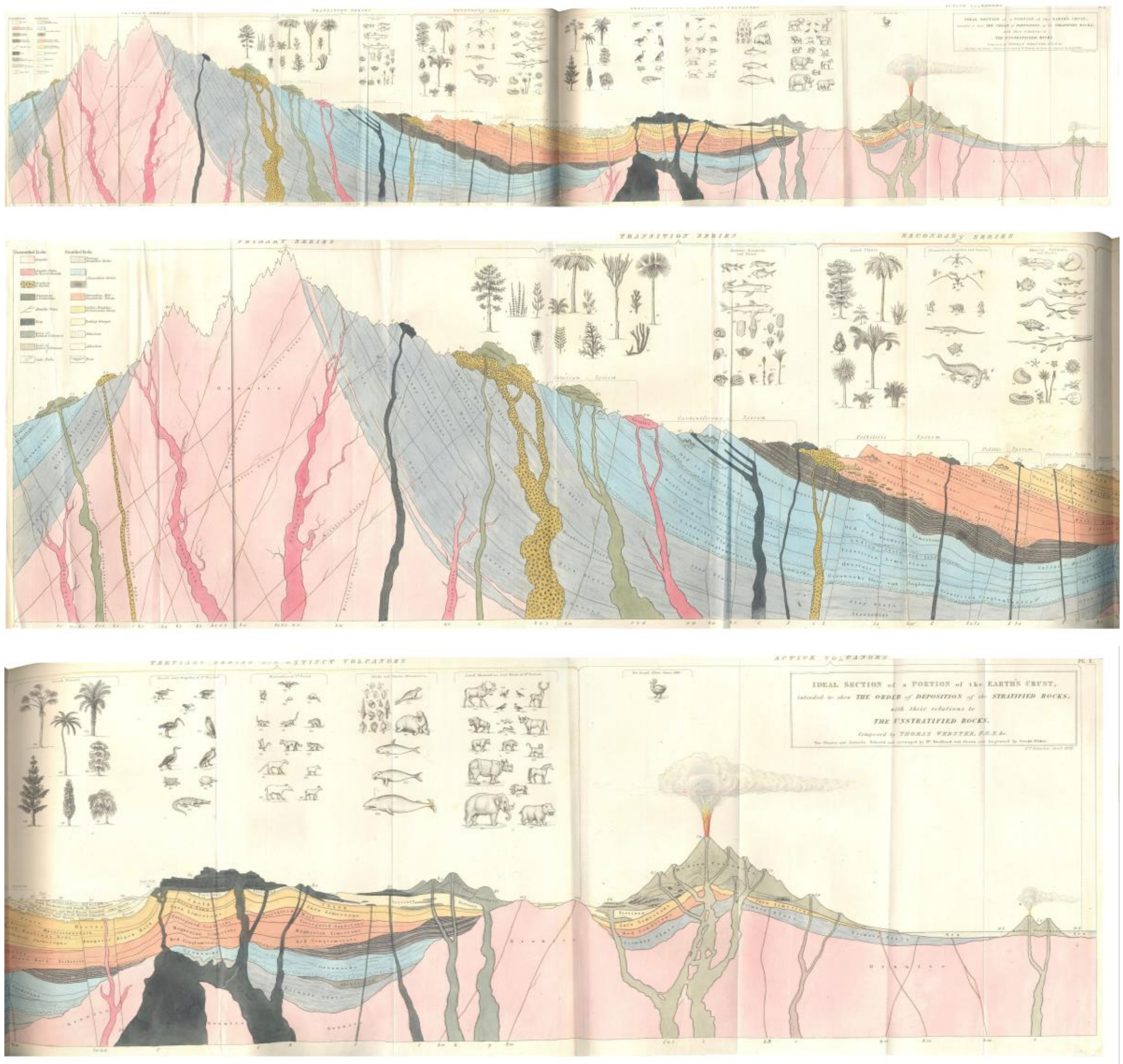

Fig. 3.7. 'Ideal Section of a Portion of the Earth's Crust' from William Buckland's *Geology and Mineralogy Considered with Reference to Natural Theology* (2: Plate 1).

provided in the natural world.[72] Natural theology often absorbed this view: Prout sees industry as an antidote to human suffering (361-362), Bell thinks man's works will result in the 'enlargement of the sources of man's comfort and enjoyment—the relief from too incessant toil' (274), and Buckland understands minerals as contributing 'to increase the riches, multiply the comforts, and ameliorate the condition of mankind' (1: 67).[73] Defences

[72] For a historical consideration of the importance of human technological industry in achieving a better world, see Noble.

[73] For Buckland, Providence has a specifically national intention in putting coal where it was: God was British for Buckland. A German observer, Herr Schonbein summarized one of Buckland's famous outdoor speeches thus: '"The immeasurable beds of iron-ore, coal, and lime-stone which are to be found in the neighbourhood of Birmingham, lying beside or above one another, and to which man has only to help himself in order to procure for his use the most useful of all metals in a liberal measure, may not, he urged, be considered as mere accident. On the contrary, it in fact expresses the most clear design of Providence to make the inhabitants of the British Isles, by means of this gift, the most powerful and the richest nation on the earth. This theme was treated by Buckland with every permissible variation, to the no small edification of the listening country people, and to my own great pleasure, even though I may not be able to accept his leading idea"' (qtd. in Gordon 82-83).

of the factory system and of human industry consistently invoke the same discourse of amelioration. Ure confidently proclaims that ‘Providence has assigned to man the glorious function of vastly improving the productions of nature by judicious culture, and of working them up into objects of comfort and elegance with the least possible expenditure of human labour—an undeniable position which forms the basis of our Factory System’ (*Philosophy* 278). Like so many of his contemporaries, Ure presents the factory as the ‘best temporal gift of Providence to the poor, a blessing destined to mitigate, and in some measure to repeal, the primeval curse pronounced on the labour of man’ (17). For Ure, industry is Providence’s way of assuaging pain.[74]

Thus the factory’s inclusion in a natural landscape designed by Providence solved a major problem within the Christian tradition: the problem of pain. The suffering of animate beings implied either that God was not benevolent or that his designs failed to produce the good intended. But factories could complete the benevolent intentions by easing human labour and providing usually scarce materials and products. Factories were not separate from, but extensions of God’s intended natural world. They could almost recreate the Garden from which humans had been expelled. Rooted in topography and the picturesque, natural theology and popular technology joined forces to paint a picture of an industrial pastoral in which the landscape was a beneficial combination of natural and artificial.[75] Indeed, this natural-artificial Providential intention could ultimately accommodate geological change, deep time, and the death of living beings, as Buckland observed:

> Thus, from the wreck of forests that waved upon the surface of the primeval lands, and from ferruginous mud that was lodged at the bottom of the primeval waters, we derive our chief supplies of coal and iron; those two fundamental elements of art and industry, which contribute more than any other mineral production of the earth, to increase the riches, and multiply the comforts, and ameliorate the condition of mankind. (1: 67)

Through the topographic vision, factories became the missing link that could bring to completion the beneficial intentions of God.

Linking natural theology and popular technology, the topographic vision in natural theology also merged with attention to the taxonomic order of nature. Peripatetic clerics scoured the countryside for new species, classifying and cataloguing animals, vegetables, and

[74] Ure, *Philosophy* 17, 278, 370, 425-26.
[75] On this merging in classical pastoral, see L. Marx, *Machine* 22-23; on the pastoral tradition generally, see L. Marx, *Machine*; R. Williams, *Country*. A very similar integration of machinery and the Providential landscape was accomplished by an American named Tench Coxe during the same period, see L. Marx, *Machine* 150-169.

minerals with geographical specificity, believing they were fulfilling a religious vocation in studying God's handiwork. While earth sciences could point to Providential intention in nature, natural history's focus on classifying natural objects revealed order in nature, implying God's existence, wisdom, and dependability. Like approaches to landscape, taxonomy also served as a contact point in the symbiosis between natural theology and popular technology. Applying natural historical forms to machines, popular technology drew on a theologically-inflected way of looking at nature, depending on the reliability of God-given order in presenting machines. But the inclusion of machines into a stable classificatory system also served natural theology by reinforcing the taxonomy it used to understand the order of nature. Symbiotically related through classification, natural theology and popular technology ultimately worked together to support social order.

Applied to nature and machines, taxonomy was historically rooted in a theology of nature which presupposed an orderly universe.[76] Classificatory natural history assumed that there was order in a divinely created world and then set out to discover that order, both for public benefit and private piety.[77] Thus order in nature was both assumed and produced by European natural history beginning in the late seventeenth century.[78] Raised a Lutheran, Carl Linnaeus saw studying nature as a religious vocation, while his religious background allowed him to see nature as a balanced and ordered creation of God.[79] Yet Linnaeus was not unique. He inherited this understanding of nature from the British philosophical tradition of Robert Boyle and John Ray, Linnaeus's hero.[80] In England, the connection between natural history and natural theology was forged in the last decades of the seventeenth century. Ray, who wrote one of the most important natural theologies of his time, *The Wisdom of God Manifested in the Works of Creation* (1691), also formulated the system and practice of British natural history, particularly a taxonomy only reluctantly abandoned by Britons when the power of Linnaeus's binomial naming system became prominent a century later.[81] For Ray, as for other naturalists, the order that was 'discovered' through natural history was really the order created by God. Some were more hesitant: Linnaeus believed that his system's problems indicated its artificiality. Yet he was confident that God's order would be

[76] According to Lewis, Christianity defined nature as the opposite of disorder (39-40).
[77] For multiple ways in which a religious framework shaped science, see Brooke, 'Religious Apologetics'.
[78] Farber 2.
[79] On his vocation, see Koerner 22; and his assumptions, see Farber 9-13.
[80] Koerner 82. Linnaeus also absorbed Boyle's anthropocentrism, seeing nature as made to benefit man and classification as the first step in man's participation in creating that benefit (Koerner 82-94). For the importance of both Boyle and Ray in the development of English natural history, see Gillespie, 'Natural'.
[81] On *Wisdom*, see Gillespie, 'Natural' 38-47; for Ray's continued importance in Britain, see Farber 35-37.

found through enough study. Alternatively, Buffon believed that his taxonomy was entirely artificial, a handy way for humans to understand nature, but not in itself real.[82] Yet most naturalists, especially in Britain, did not function within Buffon's radically unfinalizable system built on atheistic assumptions. Through the mid-nineteenth century, natural history continued to be pursued within a natural theological framework.[83] Fanned out across Great Britain and with enough money for leisure time, clergymen continued to make significant contributions to natural history until edged out during the professionalization of science in the second half of the century.[84] As a way of formulating nature's meaning, natural history and taxonomy purported to reveal the order of nature created by God, even if they actually constructed that order themselves.

While often pursued within a natural theological framework, natural history also played an important role within natural theology as a genre and apologia. Taxonomy's apologetic value was reiterated in the 1830s by the Bridgewater Treatises, over half of which make Cuvierian biological natural history central to their methods.[85] Kidd celebrates Cuvier as the 'most experienced physiologist of the present age' (42) and explores Cuvier's work and its relationship to the systems of other naturalists (298-334). Believing that complete knowledge of nature will enable humans to meet all their needs, Kidd praises Cuvier as most fully accomplishing this project (285-286). Discussing fossils at length, the biological sections of Buckland's *Geology and Mineralogy* read as applications and expansions of Cuvier's taxonomy, fitting fossilized animals and plants into it. In this world, detailed adaptation and a larger order are connected: Buckland enthuses about Cuvier's ability to re-construct an extinct animal's skeleton, tissues, and environment from a single, tiny bone. Adaptation between individual parts of an animal body and then adaptation to that body's environment signal 'a system of well connected contrivances' (1:142-143), allowing the individual contrivance to point to the universal order of nature created by a single deity. For Buckland, detailed adaptation points consistently to nature's 'Unity of Design and Harmony of Organization' (1: 109). Limiting himself to one anatomical part—the hand—Bell performs Cuvier's one bone trick but for the universal order created by God. Beginning with the hand, Bell moves outward to comparative anatomy, slowly shining a wider circle of light on design in nature. Like Kidd and Buckland, Bell depends on Cuvier *passim*, focusing on

[82] On the ontological status of this order for Ray, Linnaeus, Buffon, and others, see Dear, *Intelligibility* 39-66.
[83] Despite the continuing natural theological framework for natural history, scientific writing on natural history shifted away from using natural theology's 'explanatory' structures during the mid-nineteenth century (Gillespie, 'Preparing').
[84] For the clash between clergymen and professionalizing scientists, see F. Turner, 'Victorian'.
[85] For the importance of natural history to natural theology, see Gillespie, 'Natural'; Ospovat, 'Perfect'.

function and rejecting type in comparative anatomy. Although Roget's *Animal and Vegetable Physiology* focuses on type rather than function in the details, his structure is rooted in Cuvier's emphasis on function.[86] He organizes his physiology and comparative anatomy first by function—mechanical, vital, sensorial, and reproductive—and then by type. Roget even believes that his methodological arrangement of topics in the treatise will contribute to the reader's perception of order and 'unity of design' in nature (1: ix). Like Buckland, he concludes that physiology produces conviction of nature's unity of design. Beyond direct mentions of Cuvier, the explanatory emphasis on function and on how things are put together, discussed in chapter two, demonstrates the importance of Cuvier's work to the natural theology of the 1830s. Attentive to both function and environment within a teleological framework, this biological natural theology connects small contrivance with universal order. Where topography revealed the benevolence of the designer, taxonomy revealed his wisdom and reliability in a unified, ordered nature.

As in natural theology, taxonomy played a special role in the popular technologies written by Ure and Babbage—one that reflected both the traditional and contemporary theologies of nature implicit in taxonomy. Like the Bridgewater Treatises, Ure's *Philosophy* and Babbage's *Economy* were published when natural history was in flux between the supreme theological confidence of Ray or Linnaeus and the naturalistic explanation of Charles Darwin. In natural history, belief in God's order eroded when naturalists focused on historicizing natural forms or when they sought for natural explanations of adaptations.[87] Against this shift, Babbage's and Ure's taxonomies of factories and machines reflect a static order set in place by God. Both focusing on 'function', they use Cuvier's system, the theologically safest contemporary natural history. While Ure's factories grow organically out of their natural environments, he consistently presents the factory system as the brainchild of a single man, Richard Arkwright, who laid down the principles of modern manufacturing. By rooting the factory system in a single human mind, Ure aligns factory order with a static natural order exhibiting 'Unity of Design' because created by a single Divine mind. Babbage neglects the history of machinery or factories, describing and discussing contemporary, unhistoricized technologies. Unlike Ure, who provides a systematic classification of a specific type of industry, Babbage provides snapshots of a larger system with an incomplete list of copying techniques. Yet this incompleteness does not indicate the failure of classification; this list is just one piece of a larger puzzle. Confident in his partial list,

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[86] For Roget's teleology as anti-Cuvierian, see Ospovat, 'Perfect' 36-37.
[87] On this shift, see Ospovat, 'Perfect'.

Babbage assumes the existence and stability of the larger system. Like Christian naturalists whose incomplete taxonomies do not challenge their confidence in a real, God-given, and discoverable order, Babbage assumes that a systematic order exists. For both Ure and Babbage then, the application of taxonomy to machines both registers and draws on contemporary natural history, especially its natural theological application in the Bridgewater Treatises. These taxonomies of machines mirror the taxonomies of nature that point to God-given order. Incorporating machines into nature, taxonomy places machines in a specific order made by God. This incorporation subtly weaves a mechanical apologia into a theological one. The order projected onto nature by natural history, especially in natural theology, sanitized and idealized a God-made nature. Becoming part of this order through the application of taxonomy, machines were sanitized and idealized too.

While a theologically-shaped natural history supported and enabled mechanical apologia, the application of taxonomic forms to machines also benefited natural theology by reinforcing the value of those forms. Accomplished by Babbage and Ure, the classification of machines and factories imbued industry with order. Not only were Ure's factories in perfect internal order (as evidenced by his simple and rational diagrams, see Figs. 3.1-3.3), but they participated in an abstract order discovered by the human mind. By integrating machines into 'science', Babbage and Ure worked the machine and the factory into the universal taxonomic order created by God. The extension of natural history to machines demonstrated the universality of its forms, expanding the intellectual territory natural history could make intelligible. The more things taxonomy can explain, the better it is. Its ability to make so much of the world intelligible—animal bodies, animal instincts, geographical distributions, geological discoveries, and machines—pointed to the system's universality and thus to a Divine mind behind the physical and abstract order of the universe. The extension of natural historical forms to machines reinforced the forms and affirmed the order of the world accessed through them.

Mutually supportive projects, natural theology and popular technology joined forces in service of social order, a commitment shaped by their confidence in an orderly world. The 1830s were a time of class tension, with the status quo threatened by disruptive forces within the working class. Although the Reform Bill assuaged some of this upheaval, other techniques were employed, including both natural theology and popular technology. Taxonomy was part of this commitment through its demonstration that order itself was part of nature—part of God's plan. While natural theology's function as rhetoric for social stability stretches back into the seventeenth century, it took on particular shapes during the 1830s.[88] Intellectually, it served as common ground for a British population with increasingly diverse religious beliefs. Socially, it stabilized relations between classes.[89] Demonstrating a God-given order of nature, natural theology was used to argue that the social status quo was part of that order. In an address to a few thousand working men during the 1838 meeting of the British Association for the Advancement of Science in Newcastle, Adam Sedgwick connected the order of nature to industry, class relations, and personal piety. According to Herschel, Sedgwick

> 'led them on from the scene around them to the wonders of the coal-country below them, thence to the economy of a coal-field, then to their relations to the coal-owners and capitalists, then to the great principles of morality and happiness, and last to their relation to God, and their own future prospects'. (qtd. in Clark and Hughes 1: 515-516)

Yet appeals to the order of nature were not enough if the real disruption was man-made: the machine, the factory system, and the resultant re-organization of populations and labour structures. Enter popular technology. Implicitly working hand-in-hand with the natural theological rhetoric on social order, Babbage and Ure established that order did exist in the industrial world and that machines were actually part of the God-given natural order. Indeed, both discuss how the unruly working classes can learn discipline and submit to order. Ure asserts that when working men come into contact with the regulated action of the factory, they will learn to regulate their own minds, parroting a comment often made by those defending the study of nature.[90] By integrating nature and machines into a single order through a mutual taxonomy, natural theology and popular technology banded together in the service of the social order. Applied from natural theology to popular technology and back again, taxonomy corralled a threat to the early Victorian social order: the machine.

Not only did popular technology enable natural theology's design argument, but the two genres were symbiotically related through the contact points of topography and

[88] For natural theology and social order in the seventeenth century, see Gillespie, 'Natural'; Jacob, *Newtonians*; for the nineteenth century, see Brooke, *Science* 192-225; Topham, 'Science and Popular'. For natural theology as common ground, see Brooke, 'Why'.
[89] The conservative nature of much natural theology was the main charge by the author of *Serious Thoughts, Generated by Perusing Lord Brougham's 'Discourse of Natural Theology'* (1836), who complained that natural theology supports the hegemony of priest, prince, and Protestant (24).
[90] Ure, *Philosophy* 333-334, 340, 368. E.P. Thompson excoriates Ure for enlisting religion to assist this factory discipline (395-405). Of nature, John Herschel suggests that its 'calm, energetic regularity' serves to 'tranquilize and re-assure the mind, and render it less accessible to repining, selfish, and turbulent emotions' (16-17).

taxonomy. Assimilated into a Providential landscape through topography, machines also completed the work of Providence in nature, solving one part of the problem of pain. Machines became part of the order of nature through taxonomy while also reinforcing the power of natural history to explain the world. Indeed, natural theology and popular technology are like conjoined twins whose shared organs are taxonomy and topography.

Exposed by Hume's objections, the plausibility of the design analogy depends on the aptness of its central mechanical metaphor, on the perceived similarity between nature and human-made objects. Before around 1800, this similarity had been established by the scientific way of looking at nature as a machine. In the early nineteenth century, however, mechanical metaphors lost centrality in science. Yet natural theology continued to thrive. Although the Bridgewater Treatises of the 1830s did not deploy explicit mechanical metaphors as frequently as their predecessors, the design analogy at its core continued to be mechanical, therefore depending on the similarity of machines and nature for its aptness. With nature conceived as less-and-less mechanical in science, the similarity was now established through representations of technology. Applying methods for looking at nature to looking at machines, popular technology texts naturalized machines. Industrial tourism texts embedded machines into the natural landscape through a topographic vision while Ure and Babbage made machines part of the order of nature by classifying them. Not only did popular technology enable the plausibility of the design argument, but the two sets of texts were symbiotically related, informing and reinforcing the other through the contact points of taxonomy and topography.

The cultural impact of the naturalization of machines in a specific historical context raises larger questions about the relationship of technology and nature—and its representation. The assimilation of nature and machines in nineteenth-century popular technology points to the flexibility of both terms, to the fact that neither has an essential meaning. Thus this historical enquiry can serve as a corrective to entrenched literary and Green discourses which see nature and machines as diametrically opposed. When the similarities rather than the differences are emphasized, a way forward opens. When they are opposed, either nature or machines must be sacrificed in our environmental crisis. But when their similarity is foremost, a new relationship between physical nature and machines becomes possible. Engineers now study nature to inform the design of increasingly Green technologies, a design practice called biomimicry.[91] Physically naturalizing machines, engineers can assuage the ecological crisis by blurring the boundaries between the natural and the mechanical.

The invention of new technologies has often been mythologized by the story of Prometheus who stole fire from the heavens and gave it to man. Ironically, fire's status is ambiguous: is it natural or artificial? Indeed, the story of Prometheus does not need to be one of warning as it was in Mary Shelley's *Frankenstein*. For the Victorians, the Prometheus story was a positive celebration of the power of humanity and the progress of culture.[92] Today we can re-write the story of Prometheus to celebrate the possibility that the blurring of nature and technology can lead to an ecologically more responsible world.

[91] For recent work in this area, see Bejan and Zane's *Design in Nature*, which is about 'design in nature as a scientific discipline, centered on a physics law of design and evolution: the constructal law' (Bejan and Zane, 'Design' 43). Without any irony whatsoever, and written for a design engineering trade journal, they describe the constructal law as 'a unifying law of design in nature' (43).

[92] On Romantic and Victorian interpretations of Prometheus, see Holmes.

CHAPTER 4

Of Minds and Machines: The Laws of Nature and Divine Action in the Universe

It should be no surprise that affirmative meanings for machines, like intelligibility and naturalness, enabled the design analogy in the early nineteenth century. Seeking to demonstrate God's wisdom and goodness as well as his existence, apologists necessarily used metaphors that evoked positive connotations not negative ones. But the cultural meanings of an object—of machines in this case—are never singular, simple, or static. They are complex, contested, and constantly changing. So what happened to natural theology when the 'machine' acquired negative meanings? How did natural theology proceed when machines were problematic rather than positive?

As the 'machine' became the property and product of public culture, a growing number of negative connotations of technology complicated and undermined the argument from design.[1] Debate over the 'factory question' in the 1830s spawned a huge amount of anti-factory discourse, raising specific problems with and producing a number of negative meanings for machines which threatened to fracture and destroy natural theology. One of these anti-technology motifs resonated with a buried but crucial theological problem within natural theology: the problem of the maker's personal agency in the face of his artefact's autonomy. Critics of the factory system consistently represented factory work as slavery to machines, which rob humans of their agency and free will. Disconnecting the machine from its human designer, they understood the machine as autonomous while the human artisans were its victims. Inside natural theology, a parallel problematic of mechanism was coming to a head. Increasing naturalism in science meant that what had before been explained by direct divine action could now be explained by the laws of nature. And as many a religious critic of science pointed out, these references to laws reduced and often denied God's agency, his action in the world, while they also implied an autonomous natural world. Thus the contested relationship between humanity and machines aligned with the contested relationship between God and nature in the problems of agency and autonomy.

Much of the natural theology of the 1830s implicitly addressed the problem of whether the laws of nature could be reconciled with God's action in the universe. Although

[1] On the machine as public culture, see chapter 2.

many scholars assume the Bridgewater Treatises are suspicious of naturalistic explanation because it diminishes the God-of-the-Gaps, most of the treatises are actually open to it, seeking to assimilate the laws of nature into a theology that can also maintain God's action and intervention in the natural world. But how was the seeming autonomy of nature reconciled with the agency of God? As this theological question parallels an industrial one, so the theological and industrial answers are parallel. An emerging genre of textbooks on mechanics solved the industrial problem by putting humans back into control of machines through knowledge of the laws of physics. Emphasizing the mind behind the machine, these pro-industrial writers opened up a solution to the problem of divine agency in a law-bound world: an appeal to the mind behind the laws. Not only did negative meanings of machines raise problems within natural theology, but the answers to industrial criticism also provided solutions to a long-standing theological problem, shaping a natural theology that could accommodate laws by focusing on the mental dimension of God's agency.

Industrial Zombies: Humans versus Machines in Anti-Factory Discourse

So far this project has gone against the grain of Victorianist literary studies by setting aside the assumed antagonism between literature and technology and focusing on a literature of technology that formulated approving meanings of machines. Expositions of steam engines represented machines as intelligible rather than magical, while industrial travel narratives and taxonomies of technology represented machines as part of nature rather than opposed to it. But critiques of technology voiced by literary authors, cultural critics, political activists, and social reformers cannot be ignored. Such texts are also part of the literature of technology because they formulate meanings for machines, albeit negative ones. Thomas Carlyle's famous commentary on the 'Age of Machinery' in 'Signs of the Times' (1829) is perhaps the most-often cited example of this literature, the assumed paradigm of early nineteenth-century critiques of machinery. At the metaphorical, abstract level, Carlyle opposed the 'Mechanic' to 'Dynamic', complaining that people have 'grown mechanical in head and in heart, as well as in hand. They have lost faith in individual endeavour, and in natural force of any kind' (63). For Carlyle, mechanical people are automata who do not think for themselves but respond automatically, passively, and a-rationally to causes impressed upon them. On the other hand, dynamical people have 'natural force', actively making things happen out of their internal, spiritual will. While Carlyle prescribed a balance of 'Mechanic' guided by the 'Dynamic', his opposition between the two metaphors and his identification of passivity and a-rationality with machines was made concrete by more practically-minded critics of the factory system.[2] Publically debating the 'factory question' in the 1820s and 30s, reformers and critics presented physical machines and factory work as directly deleterious to the 'natural force' of factory workers, eroding the artisan's mental capacities and his ability to decide and act for himself. Within these debates, the machine's meaning was formulated through its antagonistic relationship with the human agent, whose agency included both physical and psychological elements.

The public and parliamentary debate on the factory question and the movement for factory reform began with the nineteenth century, but was most intense in the 1820s and 30s. Led by Tory Members of Parliament Michael Sadler and Anthony Ashley Cooper, Earl of Shaftesbury, the movement generated a plethora of discourses, texts, and rhetorics, particularly a genre of 'industrial dissent' which presented machinery's social and physical impact.[3] Parliamentary investigations depended on first-person reporting and first-hand empirical evidence, which was then widely reported by the press.[4] This blend of anecdotal and forensic approaches, compounded with a recognition of the flaws in the inspection system, precipitated a set of medical and statistical reports on the condition of the working classes in specific urban environments from the mid-1830s onward. These texts reified the opposition between humanity's mental powers and machine work, giving empirical evidence for the idea that human agency is undermined by physical interaction with machines. Perhaps the two most famous texts of this genre are a pamphlet by James Phillips Kay called *The Moral and Physical Condition of the Working Classes Employed in the Cotton Manufacture of Manchester* (1832) and the more extended report by Peter Gaskell on *The Manufacturing Population of England* (1833).[5] Such texts made the threat of machines to

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[2] Carlyle only criticizes the 'Mechanic' when it is separated from the 'Dynamic'. At the concrete rather than metaphorical level, Carlyle can assimilate industrial culture within the 'Dynamic' because he sees 'natural force' as a guide to industrial culture: in *Past and Present* (1843), Carlyle suggested that only the dynamical 'Captain of Industry' could solve the 'Condition of England' problem. Carlyle's use of the machine as a metaphor demonstrates how the 'machine' had an abstracted cultural life which was connected to—but also went beyond—its physical existence.

[3] On rhetorics, discourses, and texts of the factory movement, see Gray; and for a collection of excerpts from primary texts, see Ward.

[4] These reports and testimonies were often published in periodicals and collected into books. See, for example, Charles Wing's *Evils of the Factory System Demonstrated by Parliamentary Evidence* (1837).

[5] Gaskell's work was republished under the new title of *Artisans and Machinery* in 1836. Other works in this genre include Alex Richmond's *A Narrative of the Condition of the Manufacturing Population* (1825), Edwin Chadwick's *Sanitary Conditions of the Labouring Population* (1842), Edward Baines's *The Social, Educational, and Religious States of the Manufacturing Districts* (1843), Dan Noble's *Facts and Observations Relative to the Influence of Manufactures upon Health* (1843), Frederic Engels's *The Condition of the Working Class in England* (1844, although not translated into English until the late nineteenth century), and Henry Mayhew's *London Labour and the London Poor* (1849-1850).

human agency concrete with an eye to inducing paternalistic intervention in the factory system, the lives of the working class, and the northern industrial cities.[6]

These highly influential reports on the condition of the industrial classes concretely linked machine work with reduced human agency.[7] The most often quoted passage from Kay's frequently invoked *Moral and Physical Condition of the Working Classes* characterized factory workers as lacking in Carlyle's 'natural force':

> They are engaged in an employment which absorbs their attention, and unremittingly employs their physical energies. They are drudges who watch the movements, and assist the operations of a mighty material force, which toils with an energy unconscious of fatigue. The persevering labour of the operative must rival the mathematical precision, the incessant motion, and the exhaustless power of the machine. (24-25)[8]

A drudge, according to the *OED Online*, is 'one employed in mean, servile, or distasteful work; a slave, a hack; a hard toiler'. The word suggests that factory workers are valuable merely for physical labour, reducing them to bodies that are similar, but inferior, to vastly more efficient machines.[9] Machine work thus hollows out a worker's natural interior vitality, turning him or her into an enervated machine.

But a 'drudge' is also as a slave. Well-established by the 1820s, the slave metaphor became central to industrial reform rhetoric with Richard Oastler's invective, 'Yorkshire Slavery', published in the *Leeds Mercury* in 1830. Borrowing rhetoric and arguments from contemporary abolitionists, industrial reformers used the slavery metaphor to emphasize both the terrible working conditions in factories and the artisan's loss of freedom through the lost self-determination of his labour.[10] Indeed, John Fielden complained that workers were worse off than slaves in colonies in the sense that they were not 'free agents' (40-41). The opposite

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[6] Largely medicalizing the question of the benefit of the factory system, these texts focused on the physical bodies of workers or analogized society to a body, establishing the authority and necessity of medical men in the administration of society and the state (Poovey, *Making*).

[7] Their influence went beyond the political world, spreading also to literature: not only did British writers use these texts as sources (Brantlinger 28-32), but the British novel was transformed by these industrial dissenting discourses as it internalized and tried to embody their concerns and philosophical tensions (Gallagher).

[8] A contemporary historian noted that its publication 'accelerated the growth of public opinion in favour of factory legislation; it was the custom of Mr. Oastler and others to read extracts therefrom, corroborating the parliamentary evidence on the question, and either leaving out or replying to the educational and economical theories of the authors' (Alfred 1: 260). For a sustained treatment, see Poovey, *Making* 55-72. This passage was quoted by many, including Baines 457-460; Bray 352-353; Chalmers 2: 185-186; Fielden 37; Montagu 101.

[9] Peter Gaskell espouses a very similar view: 'the workmen are reduced to mere watchers, and suppliers of the wants of machinery, requiring in the great majority of its operations no physical or intellectual exertion; and the adult male has begun to give way' (144) and to be replaced by women and children, who are 'equally efficient servant[s] to his machinery' (146).

[10] On anti-slavery rhetoric in factory reform discourse, see Davis 453-468; Gallagher 3-35; Gray 21-47.

of slavery, 'freedom' became a central, contested, and structuring concept and discourse for the 'factory question', informed by discussions of freedom in politics, social theory, political economy, philosophy, and religion. While the factory question asked whether factory work was harmful to women and children, it also asked whether men working in factories were free.[11] For Kay and other industrial reformers, the answer was 'no' and the cause was the machine. Adapting his body to the rhythms of the machine, the artisan became a machine himself, both losing his outward freedom and his desire for it.

This slavery metaphor not only structured the conception of the human worker, but also of the machine's role in the factory. Representations of the artisan's enervating factory slavery were set against representations of the machine's growing power and autonomy. Although Kay and Gaskell do not directly condemn machinery, the language with which they treat it turns the machine into the powerfully autonomous master of humans. For Kay, the machine is 'a mighty material force, which toils with an energy ever unconscious of fatigue' (25) while Gaskell talks about 'the gigantic and untiring energies of automatic machinery' (5). Treated with language suitable to the technological sublime, Gaskell's and Kay's machines are self-existing and self-acting. Ignoring those who design or daily control machines, they focus on the people controlled by machines. Gaskell complains that:

> The labourer is indeed become a subsidiary to this power. Already he is condemned, hour after hour, day after day, to watch and minister to its operations,—to become himself as much a part of its mechanism as its cranks and cog-wheels,—already to feel that he is but a portion of a mighty machine, every improved application of which, every addition to its Briareus-like arms, rapidly lessen his importance, and tend to drive him from a participation with it, as the most expensive and unmanageable part of its materials. (143-144)[12]

Against the grain of his scientific, empirical study of factory work and life in factory towns, Gaskell switches into a sublime, mythic mode in comparing the motive machines within factories to Briareus. A storm giant of Greek myth, Briareus was one of the Hekatonkheires, or 'hundred-handed-ones', the hideously ugly yet prodigiously powerful offspring of earth and sky at the early limits of the world's history. His connotations of power, ugliness, and multi-handedness were invoked throughout the nineteenth century to express the power of

[11] On gender differentiation in debates over the 'factory question', see Gray.
[12] Opposed to this rhetoric, Baines complained that 'By these rhetoricians, the steam-engine is represented as a tyrant power, and a curse to those who work in conjunction with it' (451-452).

steam-driven industry and of the laboring classes.[13] By turning to mythic language, Gaskell personifies the machine and gives it both physical power and autonomy, making it master to the human slave. Even pro-industrial writers used the master metaphor for steam power, saying that its elements, water and fire, make the best of servants, but the worst of masters. Yet as Langdon Winner has pointed out, the question of 'autonomous technology is ultimately nothing more or less than the question of human autonomy held up to a different light' (43). Indeed the slavery metaphor is a relational one, requiring both a master and a slave. As concepts then, the human and the machine structure each other—one is defined by its relationship with the other—through this metaphor.

The slavery metaphor aptly expressed the worker's loss of external, physical freedom, but it also expressed the erosion of human freedom's mental foundation: rationality. Although outside practical agitation for reform, Wordsworth meditated on human agency amid industrialism in *The Excursion* (1814). Witnessing the end of a workday from outside a cotton mill, the wanderer describes the mechanic coming out of the mill: 'He is a slave to whom release comes not, / And cannot come. The Boy, where'er he turns, / Is still a prisoner' whose 'inward chains' imply a 'liberty of mind / Thus gone forever' (372-73). A few decades later, Kay explained exactly how factory work forged these 'inward chains':

> Prolonged and exhausting labour, continued from day to day, and from year to year, is not calculated to develop the intellectual or moral faculties of man. The dull routine of a ceaseless drudgery, in which the same mechanical process is incessantly repeated, resembles the torment of Sisyphus—the toil, like the rock, recoils perpetually on the wearied operative. The mind gathers neither stores nor strength from the constant extension and retraction of the same muscles. The intellect slumbers in supine inertness; but the grosser parts of our nature attain a rank development. To condemn man to such severity of toil is, in some measure, to cultivate in him the habits of an animal. He becomes reckless. He disregards the distinguishing appetites and habits of his species. He neglects the comforts and delicacies of life. He lives in squalid wretchedness, on meagre food, and expends his superfluous gains in debauchery. (22)

[13] *Punch*, for example, uses Briareus to represent the labouring class in an illustration in the 1890 Christmas number (4). Pro-industrial writers also invoked Briareus: Andrew Ure called the throstle and mule jenny 'the two great arms of the Manchester Briareus' in 1836 (*Cotton* 1: 44) while Baines talks about the 'Briarean power' and the 'thousand arms of the steam-engine' (*History* 212, 86).

Basically, factory work reduces the human worker to an animal by obliterating its mind. Its 'intellectual and moral faculties' have been destroyed and it mindlessly obeys its basic instincts and desires. This animal-artisan is enslaved to the machine, the overseer, and its animal passions. It has no freedom. In 1832, the *British Labourer's Protector* published a letter from Thomas Bailey, a minor Nottingham politician, reiterating Kay's opposition of the machine-animal to the free-human-as-rational: 'The Factory System … reduces the child of the poor man to the rank of an animal machine, to the condition of a breathing automaton' without the ability 'to think, to judge, to reason', making it impossible that he or she 'be qualified as intelligent and accountable agents to govern themselves' (55). Not only does factory work limit outward action, but it destroys the mind of the worker. Implicitly then, human freedom for these writers is not just about externally governing your own actions, but has a necessary internal element founded on rationality.

Although seeking to precipitate concrete, practical change, Kay's representation of the human worker antagonized by the machine tacitly engaged with inherited traditions of thought on human free will, holding in tension two inconsistent perspectives. Emphasizing the harm done by factories, Kay engages a naturalistic philosophical tradition that understands human action as determined by its environment. Kay's animal-artisan produced by factory work resembles Hume's human, whose actions are products of 'situations, passions, and characters [it] did not choose' (Baier 513), described in *A Treatise of Human Nature* (1739).[14] Likewise, Kay's artisan is the slave of its appetites: 'the artisan too seldom possesses sufficient moral dignity or intellectual or organic strength to resist the seductions of appetite' (25). But unlike Hume, Kay sees this subservience to appetite as produced by factory work, and therefore not inherent to human nature. For Kay, humans naturally have free will. But it is extinguished when their rationality is starved and destroyed. This echoes a free will tradition of thought endemic to western Christianity and espoused by Scottish Common Sense philosopher Thomas Reid in *Essays on the Active Powers of Man* (1788). Responding contrarily to Hume's determinism, Reid defines '*the Liberty of a Moral Agent*' as '*a power over the determinations of his own Will*' (323), a statement which 'supposes the agent to have Understanding and Will' (324).[15] While these traditions seem entirely incompatible, Kay integrates them by assuming that humans naturally have free will because they are rational, but that they can lose that agency through factory work, which destroys the

[14] On the Humean 'Theory of Motivations', see M. Smith.
[15] Reid challenges the Humean tradition directly (324).

mind.[16] Yet although he engages with philosophical questions, Kay was not writing abstract philosophy but a practical description of the impact of factory work on the people who undertook it. And in arguing for the detrimental impact of machines on minds, he paints a picture of the human as a dualistic combination of body and mind which has free will bound up with the choices made by the rational mind. To be human is to have freedom built on rationality. Factory work thus undermines and destroys humanness.

In the process of pursing the industrial circumstances that best supported personhood, industrial dissent offered a functional but imprecise conception of the human and its agency. It both assumed and constructed the human as free, as an agent who chooses, initiates, and determines its own actions through the powers of the rational mind. It conceived the human by distinguishing it from the machine; to be human was to be not a machine.[17] Mutually constitutive concepts, the human and the machine were bound together through the relational slave/master metaphor. On one side, machines were represented as increasingly powerful and autonomous. On the other, humans were represented as increasingly drained of their autonomy through the enervation of their minds. Machines were to blame. The opposition between human agency and the machine was concretely demonstrated by texts of industrial dissent, but it also influenced mechanical metaphors. A person without freedom of action or thought could be represented as a machine. Coleridge asserts in *The Friend* that '*Man must be free; or to what purpose was he made a Spirit of Reason, not a Machine of Instinct?*' (191). In multiple ways then, machines came to represent the opposite of freedom: they really deprived the artisan of agency while they also symbolized a person deprived of agency.[18]

Debates over the factory system in the 1830s gave the problem of human agency in the industrial world a specific shape. Human agency was dualistic, comprising internal rationality and external action. Critics of industrialism asserted that while factory work could harm the body, its really diabolical effect was destruction of the operative's mind. They pitted mind against machine. My argument that these texts of industrial dissent articulated what it means to be human in terms of mind seems like a nearly self-evident claim. Yet scholarship in the last two decades has focused on the human relationship to technology

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[16] Ironically, this integration of free will with determinism becomes an environmentalist view: a person's environment determines whether or not free will remains unimpaired. On the ubiquity of this contradiction in factory reform thought, see Gallagher 21-28.
[17] On humans and machines, see Ketabgian.
[18] Kang points out that automata, humans-as-machines, have had historically ambivalent meanings, only taking on their negative connotations in the second half of the eighteenth century (166-174).

through the body, mediated through Freud's conception of technology as 'prosthesis'.[19] But historicizing the relationship between human and machine also reveals a stronger dualist element—a concern with human agency as based on the rational power of the mind. The machine did not just threaten the human body, but it, more importantly, threatened the mind and the personal agency it guaranteed. But while complicating the relationship between humanity and the things it had created by freeing machines from human control, industrial dissent of the 1830s also offered a conception of human agency that could serve as the foundation for an anthropomorphic solution to a parallel theological problem of divine agency.

The Problems of God's Action in a Law-Bound World

While the problem of human agency in an increasingly autonomous *industrial* world troubled social reformers and critics of technology, a parallel problem of divine agency and action in an increasingly autonomous *natural* world troubled scientists and theologians in the 1830s.[20] This theological problem was not new, but an incidence of a long-standing debate within Christianity which continues to exercise thinkers today.[21] Historically, much of the debate on this problem has been about *how* God acts or how to understand God's action. But in the 1830s, the concern came to be with defending the belief that God *does* act in the world. Natural theology served an important role in this defence, implicitly theorizing God's action by identifying at least one specific historical moment in which God acted, formulating divine action in terms of choice, goodness, and wisdom. But it was also responding to specific philosophical threats to the doctrine of God's activity in the world. William Kirby, a Bridgewater author, identified one of them: naturalistic explanation of the natural world appealing to the laws of nature instead of divine action. Taking Laplace and Lamarck as his

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[19] Freud 91-92. For this scholarship, see N. Katherine Hayles's *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature and Informatics* (1999), Mark Seltzer's *Bodies and Machines* (1992), Tim Armstrong's *Modernism, Technology, and the Body: A Cultural Study* (1998), and the essays collected in Deidre Coleman and Hilary Fraser's *Minds, Bodies, Machines, 1770-1930* (2011). For an exception, see Ketabgian. Both her work and mine are guided by the technocultural texts of the 1830s and 40s, but she assumes a Romantic conception of the human in terms of feeling while mine assumes an Enlightenment conception of the human in terms of rationality.

[20] Agency and action—whether human or divine—have been knotty problems in philosophy for centuries. How is agency defined? What is an agent? What does it mean to act? How is agency characterized? Does agency imply freedom? Is action free or determined? While twenty-first century answers to these questions abound, to apply them to a theological problem in the 1830s would be anachronistic. For a sampling of conceptions, definitions, and positions in this debate, both contemporary and historical, see O'Connor and Sandes.

[21] For the major twentieth-century statements on the problem, see O. Thomas; and for summaries (and rejections) of the major solutions of the divine action problem in terms of modern science, see Nicolas Saunders.

whipping boys, Kirby claimed that their 'great object … seems to be to ascribe all the works of creation to *second* causes; and to account for the production of all the visible universe, and the furniture of our own globe, without the intervention of a *first*' (1: xxiv).

Theological suspicion of the laws of nature was common in early nineteenth-century Britain.[22] In 1819, Thomas Rennell, a prominent theologian, speaker, and legal leader, railed against French 'infidels' like Laplace, Lamarck, and their 'English copyists' who substitute law for God (7-8).[23] Rennell blamed the scientific practices of the natural philosopher: 'having long been accustomed to account for phaenomena around him from the agency of secondary causes, his contemplation is gradually withdrawn from the first great Cause of all things' (46). In 1836, William Josiah Irons, a theologian and critic of natural theology, suggested that seeing laws as efficient causes in nature ultimately deifies nature, leading to atheism (83). Laws give nature autonomy and so reduce or obviate God's action, just as the autonomy of machines reduces human agency in the industrial world. Thus the laws of nature became a major problem in discussion of divine action in the 1830s. Historically, natural theology had inherited this problem from itself—from the metaphors it used, how they had been deployed, and the ideas that modified them. Then the complication of the relationship between artisan and artefact in 1830s industrial protest made natural theology vulnerable to the implications of its own central mechanical metaphor.

While the problem of divine action in the natural world is often blamed on the Scientific Revolution's turn to the laws of nature, those laws have not always been philosophically incompatible with divine action.[24] Early modern thinkers actually saw laws as a way to capture the Aristotelian autonomous universe and make it dependent on God.[25] Denying an Aristotelian self-acting nature, mechanistic science insisted that matter was passive and therefore required both an impelling first cause and laws for continued action and direction—both of which were attributed to God.[26] These laws of nature were given their

[22] On the need to respond to scientific naturalism, see Topham, 'Teleology' 150. On British natural theologians facing the problem of law in reacting to French science, see Corsi 236-242.
[23] On Rennell's influence on Kirby and Chalmers, see Corsi 50-51.
[24] Theologians continue to see the Scientific Revolution as the root of the modern problem of God's action, see O. Thomas 3; while intellectual historians also notice this trend, see Harman, *Culture* 24. This narrative is also implicit in both the secularization and disenchantment theses, both of which have been subjected to much recent critical scrutiny. For targeted complications of the secularization narrative, see Brooke, 'Natural Law'; Jager; Lightman, 'Victorian'; Numbers, 'Science'. On the problem of laws of nature in theology today, especially in attempts to reconcile science and religion, see the essays in Watts.
[25] Brooke, *Science* 135.
[26] On the passivity of matter in mechanistic science, see Carlin; Heimann. For mechanistic science expanding God's action, see P. Harrison, 'Development' 27-28, 'Newtonian' 531; C. Taylor 161.

clearest scientific application by Newton and clearest theoretical statement by Descartes.[27] For Newton, the regularity of the mechanical laws of motion reflected God's character, but the explanatory limits of those laws pointed to God's continued maintenance of the universe.[28] For Descartes, God's immutability was the *a priori* metaphysical foundation for his confidence in the laws of nature.[29] The understanding of nature as law-bound emerged from and was rooted in a theological context, built on an understanding of God as an unchanging governor and law-giver who impressed divine commands on nature and continues to enforce them.[30] The 'laws of nature' thus had both deep theological assumptions and huge theological implications.

Yet in the long century between Newton and the Bridgewater Treatises, the conception of the laws of nature had changed, for, as Brooke observes, natural law is and always has been an ambiguous and flexible concept claimed by both sacred and secular ('Natural Law').[31] In the eighteenth century, matter began to be active again, while in the early nineteenth century, the concept of the laws of nature was in flux, expanding beyond the mechanical sciences—beyond astronomy and physics—to geology, zoology, and natural history.[32] Geology opened the prospect of a world much older than 6,000 years and opened

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[27] Despite the common complaint that a thorough history of the concept of the 'laws of nature' has never been written, many have provided chronologically narrow histories of the emergence of the concept: on the roots of the 'laws of nature' in ancient theories of natural law, see Lehoux; on the ancient roots of the lawfulness of nature and the idea that 'laws of nature' could only become central to science in a certain political system, see Zilsel; on the history of the concept from antiquity to Newton traced in mostly theological and metaphysical writers, see Padgett; on the roots of the concept in the medieval mathematical tradition, see Ruby; on the concept's source in and interaction with the philosophical concept of 'natural law' from 1550-1750, see the essays collected in Daston and Stolleis; on the diversity of views of the 'laws of nature' among the big five early modern scientists—Galileo, Descartes, Bacon, Boyle, and Newton, see Steinle, 'Amalgamation'; on the development of the use of the phrase 'laws of nature' (as distinct from the concept of nature exhibiting regular behaviour) and its currency, despite its imprecision, by the late seventeenth century, see Steinle, 'Principles'; on the emergence of the 'laws of nature' in the seventeenth century both as a concept and as the form in which scientific explanation was couched, see Milton; on the theological understandings and justifications given to laws in the seventeenth century, see P. Harrison, 'Development'; on theology serving to validate a pre-conceived idea of laws of nature for Descartes and on the historiography of the laws of nature, see Henry, 'Metaphysics'; on the ambiguity of the concept of 'laws of nature' in the nineteenth century, see Brooke, '"Laws Impressed"', 'Natural Law'; on Darwin's multiple uses of the concept, see Gillespie, *Charles* 54-57.

[28] As Richard Bentley presented Newton's views in his Boyle Lectures for 1691-92, with Newton's blessing: gravity, 'the great basis of all mechanism, is not itself mechanical, but the immediate *fiat* and *finger* of God, and the execution of divine law' (Bentley 75; qtd. in P. Harrison, 'Newtonian' 537).

[29] On Descartes as the originator of the modern conception of the laws of nature, see Henry, 'Metaphysics'.

[30] On the scholarly tradition which sees the laws of nature as emerging directly out of theological assumptions, goals, and discussions, see Armogate; Oakley; Osler, *Divine*; Padgett; Zilsel. On the roots in the conception of God as *deus legislateur*, see Armogate; and on the importance of God's immutability for Descartes's conception of the lawfulness of nature, see Henry, 'Metaphysics'; Milton 686. While a few have denied the theological roots altogether (Ruby), the newest scholarship upholds the theological origin of laws while softening the claim, see P. Harrison, 'Development'; Henry, 'Metaphysics; Steinle, 'Amalgamation'.

[31] Brooke, 'Between', 'Natural Law'. Kirby's own use of 'law' was a 'double entendre' having both 'spiritual and natural connotations' (Blaisdell 168).

[32] On the returning activity of matter, see Desmond, 'Artisan' 96-97.

the question of a static single point of creation. Did laws account for geological changes or did direct divine intervention? Concurrently, the model of laws as ontic, directive regularities in physics was being transferred to the life science. In the radical physiology of the 1820s, the mind was seen as the product of matter, determined by the laws of biological substances. In natural history, Lamarck presented a world in which the laws of nature could account for life and for the shapes, interactions, and activities of organisms, including humans. In cosmology, Laplace appealed to the laws of nature, rather than divine fiat, to account for the existence of the solar system, and therefore the conditions necessary for life.[33] While the Newtonian laws of nature—or mechanical laws of matter and motion—left ample space for God to act in the non-mechanical interstices of nature, the expansion of law beyond physics made God's action increasingly unnecessary to account for the universe. As Kirby complained, Laplace presented 'an Author of Nature … as perpetually receding, according as the boundaries of our knowledge are extended, thus expelling, as it were, the Deity from all care or concern about his own world' (1: xxii).[34] In just over a century, the conception and application of the laws of nature had changed from being compatible with divine action to being opposed to it.

Although some scholars see this as the teleological 'purification' of laws of nature from their theological baggage, there was nothing inevitable about the separation of laws from the theological matrix.[35] Ironically, it was the metaphor at the heart of mechanistic science and natural theology that, when grafted onto traditional theological debates, created tension between laws of nature and divine action, even while it seemed to theorize that action. Modern science and theology inherited both theological debates and battle lines from their Christian predecessors. Medieval theology bequeathed two basic formulations of God's relationship to his creation: voluntarism and intellectualism.[36] Voluntarism emphasizes

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[33] On Laplace's theological challenge, see Numbers, *Creation*.

[34] Kirby here echoes almost verbatim a statement by Laplace in *A Philosophical Essay on Probabilities* (1819): 'All events, even those which on account of their insignificance do not seem to follow the great laws of nature, are a result of it just as necessarily as the revolutions of the sun. In ignorance of the ties which unite such events to the entire system of the universe, they have been made to depend upon final causes or upon hazard, according as they occur and are repeated with regularity, or appear without regard to order; *but these imaginary causes have gradually receded with the widening bounds of knowledge and disappear entirely before sound philosophy, which sees in them only the expression of our ignorance of the true causes*' (3, my italics).

[35] On the continued theological baggage, see Osler, *Divine* 224-225, 235-236.

[36] For definitions and descriptions, see Osler, *Divine* 15-34; P. Harrison, 'Voluntarism and Early'. On the roots of mechanistic science in these two approaches of medieval theology, see Oakley; Osler, *Divine*. Traditional scholarship links voluntarism with empiricism and intellectualism with Cartesian *a priori* deductive rationalism in the practices of science (Osler, *Divine*). This 'voluntarism-and-science' thesis has recently been the subject of a debate between Harrison and Henry (P. Harrison 'Voluntarism and Early'; Henry, 'Voluntarist'; P. Harrison, 'Voluntarism and the Origins'). On the usefulness yet ironic damage of voluntarism to theistic science, see Brooke, 'Science and the Fortunes' 7-10.

God’s freedom, will, and omnipotence. For voluntarist scientists like Newton and Boyle, the laws of nature were the product of God’s free will; he was free to have chosen other laws and he could intervene in his creation at any time.[37] This highlights God’s power and outward freedom. Intellectualism, on the other hand, emphasizes God’s wisdom, foresight, and omniscience, bordering on making the laws of nature necessary products of the structure of God’s mind and character. The natural world was thus set from its beginning to function as God willed. Where voluntarism presented a hands-on God, intellectualism presented a hands-off. Yet while they emphasize different aspects of God’s character, they both assume that God exists and is in relationship with nature.

After Newton, this theological debate was re-framed through the mechanical design analogy built on the new science’s central metaphor. A series of open letters in 1715-1716 between Gottfried Wilhelm Leibniz and Samuel Clarke, one of Newton’s bulldogs, staged this reframing. Leibniz critiques Newton’s voluntarist confidence in God’s continual maintenance of the universe by mapping Newton’s view onto a mechanical metaphor. Newton’s God, according to Leibniz

> wants to wind up his watch from time to time: otherwise it would cease to move. He had not, it seems, sufficient foresight to make it a perpetual motion. Nay, the machine of God’s making, is so imperfect … that he is obliged to clean it now and then by an extraordinary concourse, and even to mend it, as a clockmaker mends his work; who must consequently be so much the more unskilful a workman, as he is oftener obliged to mend his work and to set it right. (Alexander 11-12)

Yet Leibniz does not object to the metaphor, but to not following it out completely: ‘I maintain [the creation] to be a watch that goes without wanting to be mended by him … God has foreseen everything’ (18). Leibniz makes the relation between artefact and artisan central to conceptualizing God’s action, emphasizing God’s wisdom rather than his power as the logical implication of the artisan-artefact analogy (17-19).

Although mechanical metaphors had been introduced by largely voluntarist scientists in the seventeenth century, the metaphors actually favoured intellectualism.[38] Indeed, seeing the world as an artefact of God’s making seemed to create the intervention problem—or at least make it worse—by giving the relation between artisan and artefact an explicit, concrete

[37] On Newton, see Guerlac; on Boyle, see Carlin. For Newton’s changing conceptions of divine activity in the world, see Dobbs. Even Descartes could be read as a voluntarist, see P. Harrison, ‘Voluntarism and Early’.
[38] On voluntarism as orthodoxy in England’s natural philosophy, see Milton 694.

shape. It anthropomorphically assumed that the artefact was independent from the artisan and judged the quality of the artefact and its creator from whether the artefact ran by itself, ontologizing the laws and systems of nature. The regular and unchanging laws of nature made mechanical intellectualism possible as they allowed God to create and then program the world to function without his constant oversight and correction. Thus the introduction of a mechanical metaphor and its expansion into a divine design analogy complicated the problem of divine action, making it impossible to reconcile God's power with his wisdom and favouring a universe which ran by itself without the tinkering of a divine mechanic. While both views were compatible with Christian theism, the intellectualist leanings of mechanical metaphors deepened the problem of divine action by limiting God's outward activity to the original creation of matter and its laws.

Through mechanical metaphors, then, the problem of divine action became the problem of law. The battle lines between Clarke and Leibniz, demarcated by their uses of mechanical metaphors to describe God's relation to the natural world, were swelled in the great religious debates of the eighteenth century—and made more aggressive and antagonistic. The voluntarist position developed into a full defence of miracles while the intellectualist developed into deism, with an increasing antagonism between them.[39] At issue was not just how God related to what he had created, but *if* he continued to act in it after its origination. Yet the tensions between voluntarism and intellectualism and between miracles and laws that accumulated around mechanical metaphors were not hardened into militant opposition until David Hume's infamous definition of a miracle as 'a violation of the laws of nature' ('Miracles' 210) in 1748.[40] Hume's simple definition assumes ontic laws of nature—that they really exist independently in nature—drawing out Leibniz's intellectualism and his belief that divine intervention somehow violates the order created by God.[41] Where early Newtonians could assimilate laws and miracles, Hume made laws and miracles incompatible conceptions of God and of his relationship to the universe.[42]

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[39] On intellectualism and deism, see Heimann; A. Cohen. On eighteenth-century deism, see Byrne 52-110; Jacob, 'Christianity'; Stephen. On the eighteenth-century debate on miracles, see Burns. Theologians turned to natural theology to conceptualize God's action at the beginning, and to miracles as evidence of God's continued action in and care for the world he made. On the theology of science as response to the threat of deism and atheism, see Henry, 'Voluntarist'; P. Harrison 'Newtonian'. On natural theology conceptualizing God's action, see Osler, *Reconfiguring* 89-93

[40] For Hume's attack on miracles as re-writing the objections raised by earlier deists to miracles, see Burns 72-95, 131-246.

[41] For Leibniz's views, see Alexander 20, 29-30, 42-43, 90-91.

[42] On this move by Newtonians, see Gascoigne 227-228; P. Harrison, 'Newtonian'.

Hume's definition of miracles still structures understandings of miracles today, both at the popular level and in theology. Nicolas Saunders, for example, understands a miracle to be a 'special divine action' that

Hume's conception of miracles as violations of real, concrete laws of nature makes this denial of miracles the product of a confidence in a clockwork universe governed by laws, something theological critics of law realized. In 1715, Samuel Clarke complained about the watch metaphor: 'the notion of the world's being a great machine, going on without the interposition of God, as a clock continues to go without the assistance of a clockmaker; is the notion of materialism and fate, and tends … to exclude providence and God's government in reality out of the world' (Alexander 14). And in 1843, Thomas Carlyle indignantly asserted that 'the ALMIGHTY MAKER is not like a Clockmaker that once, in old immemorial ages, having *made* his Horologe of a Universe, sits ever since and sees it go! Not at all. Hence comes Atheism' (*Past* 127).[43] This narrative is familiar to later scholars: historically, the perception of the world as a machine led to deism, as God could set the world running and then walk away from it. And from deism to materialism or atheism was only a tiny—and logical—next step.[44] Conceptualizing nature as a machine and God as its designer thus was the foundation of the opposition between laws and miracles.

The 1830s problem of divine action at the centre of science-and-religion debates was structured by these inherited concerns. Deism continued to be both a perceived and an actual threat, but an even more dangerous one in that it now denied miracles altogether and was associated with working-class radicalism.[45] Printer Richard Carlile forged this new connection between deism and radicalism by his reprinting throughout the 1820s of Thomas Paine's deistical *Age of Reason*—and by his subsequent sensational trial for and conviction of blasphemy for printing it.[46] This deism was also linked to the naturalism of Frenchmen like Lamarck, Laplace, and D'Holbach, which appealed to laws rather than God to explain nature, making law the shape of the divine action problem.[47] In England, geology, natural history,

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is an intervention in the laws of nature (48-82). The problem of laws and God's intervention is still a serious one in religion-and-science studies. For an abstract discussion of the problem of laws for Special Divine Action, see Saunders 48-82.

[43] In the 1820s, mechanical metaphors used to describe the animal or human body were feared for their association with materialism (Topham, 'Science and Popular' 418).

[44] M. Buckley gives the major statement of this view, which is a significant strand of both the secularization and disenchantment theses. In his ironic critique of deism and Christianity, 'A Refutation of Deism' (1814), Percy Bysshe Shelley throws out deism as a false step. Instead, one should go straight to atheist materialism where 'the laws of motion and the properties of matter suffice to account for every phenomenon' (116).

[45] In 1836, William Josiah Irons warned of an invasion of deism, claiming that deism rather than atheism was the great threat to English Christianity (4-7, 10-11, 122-127, 161, 182-183).

[46] On the perceived association of Carlile with Paine and deism, see E. Thompson 791-799. On the centrality of Carlile's publication and packaging of Paine to the development of British secularism, see Royle; and for its statement of deism, see Budd 10-34. On the cultural importance of Carlile's trial for blasphemy, see Marsh 60-77. For his denial of miracles, see Paine 47-50; and for objections by contemporary theologians, see Rennell 2.

[47] On the association of deism with French naturalism and English radicalism, see Budd 10-34; Corsi 57; Desmond, 'Artisan' 80-81; Marsh 20-21. D'Holbach's atheistic *Le System de la Nature* was a prime example of

physiology, and astronomy offered increasingly naturalistic explanations for what happens in nature, appearing to give the 'laws of nature' the credit formerly given to God.[48] This seemingly deistical science was also linked with the native tradition of natural theology by conservative theologians.[49] For, as Clarke and Carlyle pointed out, seeing nature as a clock led to materialism and atheism, to an exclusion of God from nature. Yet natural theology also had a large part to play in theorizing God's action in the universe.[50] Thus natural theology had an ambivalent relationship to the problem of divine action in the 1830s: it was an easy way to conceptualize God's creative action in and care for his creation, yet the metaphor on which natural theology was built favoured a world that downplayed God's action, a world which God created and then abandoned, leaving the pre-programmed laws of nature to follow their courses.

The Bridgewater Treatises inherited this ambivalence and implicitly tried to address it. The bequest was organized around God's character, rather than his existence. It celebrated the 'power, wisdom, and goodness' of God, ignoring distinctions between those characteristics and the conceptions of God's action they imply.[51] But the completed Treatises were also explicitly concerned with the problem of divine action, both in terms of laws and in terms of the impact of metaphors for them, for, as Harman points out, the central concern of natural theology was discovering what role could or should be left for God in a clockwork universe (*Culture* 25). Softening, but taking up the perspectives of Clarke and Carlyle, William Prout, for example, allowed that William Paley's mechanical metaphors diminished the perception of divine agency because they presented an autonomous world that ran without intervention (10-12). Yet while they registered that law and its metaphors were problematic for divine action, they also recognized that law was how contemporary science worked. In general, their challenge was not to deny law, but to assimilate it with divine action by dealing with the complications its own central metaphor had raised.

Thus 1830s natural theology faced a problem of its own making: mechanical metaphors had deepened the divine action problem through their relationship to law. Yet

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the partnership between mechanism and materialism in postulating a God-less universe. For the continued bundling of mechanism and materialism, see McPherson 74; Schofield.

[48] On the increase of naturalistic explanation in nineteenth-century English science, see Gillespie, 'Preparing'. For complications of this view, see Brooke, 'Religious Belief'; Fyfe, 'Reception'; Gillespie 'Preparing' 96.

[49] Irons 33, 122, *passim*. For brief discussions of the perceived association of natural theology and natural law with deism, see Astore 53-59; Baxter; Brooke and Hooykaas 16; Fyfe, 'Reception' 321. For complications of this thesis, see Brooke, 'Science and the Fortunes' 9-12, 'Why' 58-59; Brooke and Cantor 195-200.

[50] On natural theology conceptualizing divine activity in the seventeenth and eighteenth centuries, see Brooke, *Science* 117-151.

[51] Emphasizing God's power can lead to voluntarism, while his wisdom can produce intellectualism.

while the problem of divine action was implicitly structured by received notions of how to conceive of God's action in the creation, it was also shaped by and responded to contemporary problems and contexts. In *Sartor Resartus* (1833-34), Carlyle's main character, Herr Teufelsdröckh, discerns that '"Deep has been, and is, the significance of Miracles"'. For the Professor, those who see miracles as Humean law-violations also believe '"'the Machine of the Universe [is] fixed to move by unalterable rules'"' (173). For Carlyle, machines and miracles are opposing conceptions of the world, and implicitly of God, as he explicitly connects denial of God's agency with seeing the natural world as a machine. Here Carlyle taps into the received theological controversy between intellectualism and voluntarism, but he also invokes the contemporary fear that machinery threatens human agents, depriving them of their ability to intervene in the world around them. When the divine designer is understood through comparison to a human designer, any complication of the relationship between the human artisan and the artefact complicates the design analogy.[52] Discourses on both human and divine agency betrayed a fear that the agency of the human/divine designer was threatened by the perceived growth in the autonomy of the industrial/natural invention. While the problem of industrial agency was widening fissures in natural theology's plausibility structure, its conceptualization of human agency in relationship to the machine also opened the door to a possible solution to the theological problem.

Mechanics Textbooks: Mind over Machine

Anti-industrial anxieties about the erosion of human agency did not go unanswered. Competing to control the meaning of machines, pro-industrial writers made a surprising move: they deployed the same master/slave rhetoric as anti-industrialists, but used it the other way around. In *Factories and the Factory System* (1844), William Cooke Taylor patronizingly contradicted Kay's ubiquitous statement about factory drudges by describing 'the tourist, visiting a factory district for the first time' whose:

[52] While the industrial and religious problems of agency shared main terms in the conceptualization of agency in terms of inward rationality and outward potency, the relationship between those elements was configured differently in each discourse. For theologians, the design analogy in the context of the problem of divine action created an opposition between God's wisdom and his power, between his rationality and his outward action. For critics of industrialism, the machine destroyed both of these elements of human agency, first eroding his internal rationality and thus depriving him of his external freedom to act, uniting them in opposition to the machine.

> earliest impression is that fire and water—proverbially the best servants and the worst masters—have here established despotic dominion over man, and that here matter has acquired undisputed empire over mind. It requires time and patience, repeated observation, and calm reflection, to discover that the giant, steam, is not the tyrant but the slave of the operatives …. (11-12)

In reversing the master/slave rhetoric, he implicitly reverses the idea that matter has dominion over mind.[53] Instead mind had mastered matter.

Yet this was not just an empty and arbitrary contradiction of anti-industrial discourse; it was built on historical precedent and contemporary support. Historically, pro-industrial mastery rhetoric inherited the Baconian project of mastering nature, deploying machines as the tools of that mastery.[54] The Baconian aphorism 'knowledge is power' was a potent and ubiquitous ideology to the pre- and early-Victorians, explaining how humans gained control over matter through machines.[55] Defining power in terms of knowledge rather than brute force, Bacon provided a way to reconcile human agency with technology: machines are controlled when they are known. Building on this Baconian tradition, a series of texts on mechanics in the first third of the nineteenth century established knowledge of machines, and therefore human control over them. Demonstrating that machines were reducible to the mathematical laws of motion, texts on mechanics represented machines as products of human rationality, controlled through knowledge. Mechanics' became the subject of a surprising number of texts in the nineteenth century. In the first four decades, around twenty-five works on the topic were published, many going through multiple editions (Table 4.1).[56] Most included 'mechanics' in the title, several in some variant of *A Treatise on/of Mechanics*.[57] It was also a topic nested within 'Mechanics' became the subject of a surprising number of

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[53] Others also flipped this rhetoric, see Baines 10, 52; Carlyle, 'Signs' 81; Guest 3.
[54] On eighteenth-century acceptance of machines as 'justified by the view that nature can, and should, be tamed' (285), see Stewart. Pérez-Ramos has argued that Bacon's idea of science itself emerged from the 'maker's knowledge tradition' in which a person knows x because he made/did x.
[55] On the cultural importance of Bacon in the nineteenth century, see Pérez-Ramos 20-27; J. Smith, *Fact*; Yeo, 'Idol'. On Watt's inventive process as Baconian, see Arago 61. For example, this aphorism helped sell education to working-class men. Instead of agitating for political reform, they could gain power through education, or so the middle-class peddlers of self-culture claimed. On knowledge culture in Victorian Britain, see Rauch. The thesis that knowledge is power is not defunct: Foucault reiterated it in much of his work.
[56] The list of texts in Table 4.1 began with a Google Books search for texts on 'mechanics' published between 1800 and 1845. These results can be obtained by searching for 'intitle:"mechanics"', narrowing the results by date to 1/1/1800 to 31/12/1845, and finally sorting mechanically for books published in Great Britain. For the sake of brevity, I have ignored titles which use 'mechanics' in reference to the occupation of being a mechanic, like John Nicholson's *The Operative Mechanic* (1825) or the *Mechanic's Magazine* begun in 1823.
[57] Bridge; O. Gregory; Lardner and Kater; Moseley, *Treatise*; Poisson; Whewell, *Elementary* in Table 4.1. All references to Whewell, *Elementary* are to the first edition, unless otherwise noted.

		Table 4.1: Treatises on Mechanics, 1805-1842		
Date (eds.)	**Author**	**Title**	**Place**	**Audience**
1805 (1st) 1806 (2nd) 1823 (3rd) 1837 (10th)	James Ferguson (ed. David Brewster)	*Lectures on Select Subjects in Mechanics, Hydrostatics, Hydraulics, Pneumatics, Optics, Geography, Astronomy, and Dialling*	Edinburgh and London	General, Artisans
1806 (1st) 1815 (3rd) 1826 (4th)	Olinthus Gregory	*A Treatise of Mechanics, Theoretical, Practical and Descriptive*	London	Scientific, Practical Men
1807	Thomas Young	*A Course of Lectures on Natural Philosophy and the Mechanical Arts*	London	General, Scientific
1813 (1st) 1814 (2nd)	Bewick Bridge	*A Treatise on Mechanics: Intended as an Introduction to the Study of Natural Philosophy*	London, Oxford, and Cambridge	University Students
1819 (1st) 1824 (2nd) 1841 (6th) 1846 (7th)	William Whewell	*An Elementary Treatise on Mechanics*	Cambridge and London	University Students
1822	John Robison (ed. David Brewster)	*A System of Mechanical Philosophy*	Edinburgh	Scientific
1822	Giuseppe Venturoli (trans. Daniel Cresswell)	*Elements of the Theory of Mechanics*	Cambridge	University Students
1823	Giuseppe Venturoli (trans. Daniel Cresswell)	*Elements of Practical Mechanics*	Cambridge	University Students
1823 (1st) 1832 (2nd)	William Whewell	*A Treatise on Dynamics, Containing a Considerable Collection of Mechanical Problems*	Cambridge and London	University Students
1824 (1st) 1825 (2nd) 1828 (4th) 1831 (5th)	Robert Brunton	*A Compendium of Mechanics, or Textbook for Engineers, Mill-Wrights, Machine-Makers, Founders, Smiths, &, Containing Practical Rules and Tables*	Glasgow, London, Birmingham, Edinburgh	Practical Men, Artisans
1825 (1st) 1836 (2nd)	William Emerson (ed. G. A Smeaton)	*The Principles of Mechanics*	London	Students, Artisans
1825 (1st) 1837 (2nd) 1839 (3rd)	James Ferguson (ed. C. F. Partington)	*Lectures on Select Subjects in Mechanics, Hydrostatics, Hydraulics, Pneumatics, Optics, and Astronomy*	London	General
1827	Thomas Jackson	*Elements of Theoretical Mechanics: Being the Substance of a Course of Lectures on Statics and Dynamics*	Edinburgh	University Students
1829	[SDUK]	'On Mechanical Agents or Prime Movers' and 'Mechanics: Elements of Machinery' in *Natural Philosophy* Vol. 1	London	Working Men
1829	James Hay	*A Concise System of Mechanics in Theory and Practice*	Edinburgh	Practical Men
1830	Robert Walker	*The Elements of the Theory of Mechanics*	Oxford	University Students

1830 (1st) 1852 (2nd)	Dionysius Lardner and Henry Kater	*A Treatise on Mechanics*	London	General
1832	William Whewell	*First Principles of Mechanics, with Historical and Practical Illustrations*	Cambridge and London	General
1833	James Hann and Isaac Dodds	*Mechanics for Practical Men*	Newcastle-upon-Tyne	Practical Men
1834 (1st) 1839 (2nd) 1847 (3rd)	Henry Moseley	*A Treatise of Mechanics, Applied to the Arts*	London	General, Practical Men
1837 (?) 1845 (4th) 1850 (?)	Alexander Jamieson	*Mechanics for Practical Men*	London	Practical Men
1839 (1st) 1848 (4th)	Henry Moseley	*Illustrations of Mechanics*	London	General
1841 (1st) 1870 (2nd)	Robert Willis	*Principles of Mechanism, Designed for the Use of Students in the University and for Engineering Students Generally*	London	University, Engineering Students
1841	William Whewell	*Mechanics of Engineering: Intended for Use in Universities, and in Colleges of Engineering*	Cambridge and London	Engineering Students
1842	S.D. Poisson (trans. Henry H. Harte)	*A Treatise of Mechanics*	London and Dublin	Students of Physics

texts in the nineteenth century. In the first four decades, around twenty-five works on the topic were published, many going through multiple editions (Table 4.1).[58] Most included 'mechanics' in the title, 'Mechanics' became the subject of a surprising number of texts in the nineteenth century. In the first four decades, around twenty-five works on the topic were published, many going through multiple editions (Table 4.1).[59] Most included 'mechanics' in the title, several in some variant of *A Treatise on/of Mechanics*.[60] It was also a topic nested within works on natural philosophy, suggesting that it was a category of knowledge for early nineteenth-century historical actors, although one not necessarily identical with ancient or twenty-first-century conceptions of mechanics.[61] Whether referring to a textual genre or

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[58] The list of texts in Table 4.1 began with a Google Books search for texts on 'mechanics' published between 1800 and 1845. These results can be obtained by searching for 'intitle:"mechanics"', narrowing the results by date to 1/1/1800 to 31/12/1845, and finally sorting mechanically for books published in Great Britain. For the sake of brevity, I have ignored titles which use 'mechanics' in reference to the occupation of being a mechanic, like John Nicholson's *The Operative Mechanic* (1825) or the *Mechanic's Magazine* begun in 1823.

[59] The list of texts in Table 4.1 began with a Google Books search for texts on 'mechanics' published between 1800 and 1845. These results can be obtained by searching for 'intitle:"mechanics"', narrowing the results by date to 1/1/1800 to 31/12/1845, and finally sorting mechanically for books published in Great Britain. For the sake of brevity, I have ignored titles which use 'mechanics' in reference to the occupation of being a mechanic, like John Nicholson's *The Operative Mechanic* (1825) or the *Mechanic's Magazine* begun in 1823.

[60] Bridge; O. Gregory; Lardner and Kater; Moseley, *Treatise*; Poisson; Whewell, *Elementary* in Table 4.1. All references to Whewell, *Elementary* are to the first edition, unless otherwise noted.

[61] Based on seeing 'mechanics' as a category recognized by the historical actors, I expanded the list in Table 4.1 to include works which gave serious treatments to 'mechanics' but did not include the word in the title. In

category, these authors consistently describe ‘mechanics’ as a ‘science’, defining it as either 1) the science of equilibrium and motion or 2) the science of the action of motion, force, or bodies on other bodies.[62] Treatises focused solely on mechanics usually begin with its definition and that of other important terms like mass, matter, velocity, force, motion, and gravity, before proceeding to mathematical demonstrations and applications of the principles of mechanics which comprise the remainder of the work. Describing the actions of and on bodies, they emphasize either motion or force, generally concentrating on their ‘resolution’—the calculation of the resultant from the combination of two or more motions or forces—for a body or given bodies. Naturally, these resultants are calculated mathematically and are often described in the form of classical logic with propositions, axioms, and correlatives accompanied by geometrical diagrams, drawings, or illustrations (Fig. 4.1).

Despite their structural and methodological consistency, these texts are diverse, varying in form, function, publication and distribution process, authorial credibility, and intended audience in overlapping clusters of texts. Some texts are part of university education in physics and mixed mathematics, particularly at Cambridge, written by university lecturers or translated by university fellows from scientifically and mathematically more advanced foreign texts.[63] But university tutors also wrote for popular audiences.[64] Other texts were written for practical men and had a range of authors from university fellows to surveyors.[65] This audience is ambiguous: are they working-class workmen or lower-middle-

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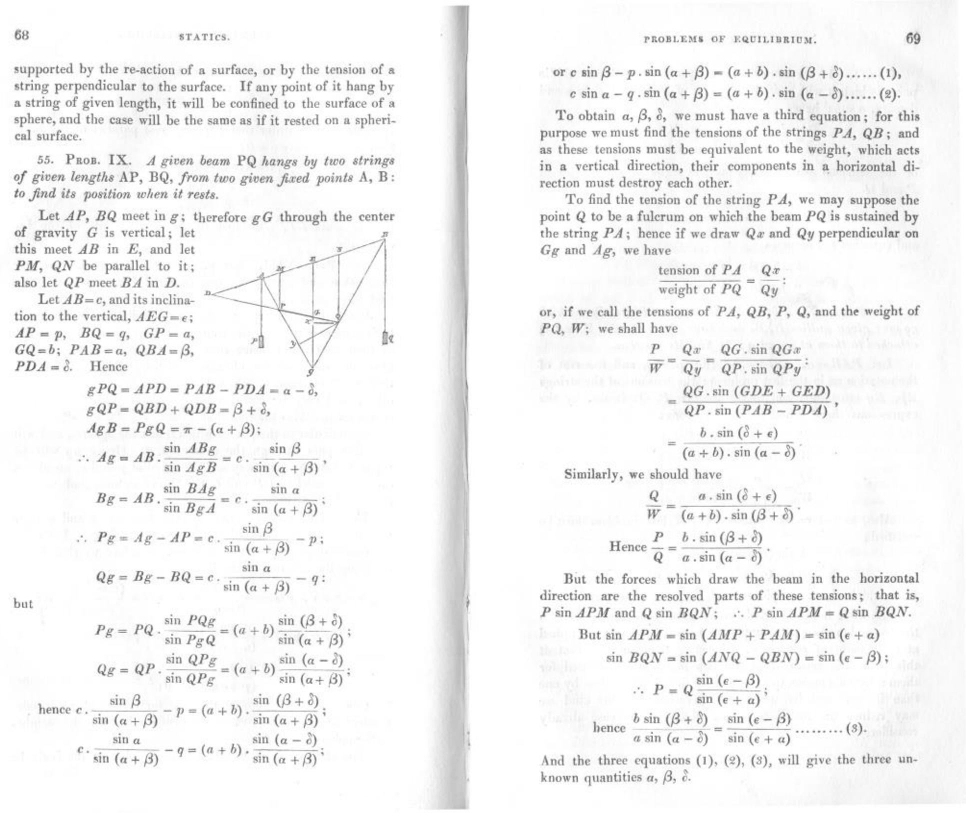
general, these were texts of natural philosophy more generally or which use some close synonym of ‘mechanics’ like ‘mechanism’ or ‘mechanical philosophy’. I was often led to these texts through the references in works with ‘mechanics’ in the title, as authors sought both to differentiate their work from that of others and to garner authority for their texts by constructing a tradition of writing about mechanics. Thus this is not a complete list of texts that treat ‘mechanics’ seriously.

[62] Those defining mechanics in terms of equilibrium and motion include Jamieson v; Poisson 1: 1; Venturoli, *Theory* 1; Walker 1; Whewell, *First* 1. Those defining it in terms of action on bodies include Emerson 1; O. Gregory 2: 1; Hann and Dodds 1; Hay 1; ‘Mechanics: Elements’ 1; Moseley, *Treatise* 17. Those offering no definition are Bridge; J. Ferguson; Thomas Jackson; Lardner and Kater; Robison, *System*; T. Young, although this lack of definition is difficult to interpret.

[63] University texts by lecturers include Bridge (East-India College); Thomas Jackson (St. Andrews); Walker (Wadham College, Oxford); Whewell (Cambridge), *Elementary*, *Mechanics*; Willis (Cambridge). Venturoli’s 1817 text in Italian was translated by a Cambridge tutor (Cresswell), while Poisson’s 1817 text in French was translated by a fellow of Trinity College, Dublin (Harte). For a brief history of Whewell’s textbooks, see Fisch 39-56.

[64] Moseley (King’s College, London), *Illustrations*; Whewell (Cambridge), *First*.

[65] Emerson, O. Gregory, Hann, and Jamieson were primarily authors and teachers on scientific and mathematical subjects; Dodds was a civil engineer; Moseley (King’s College, London), Willis (Cambridge), and Whewell (Cambridge) held university posts; Hay was a surveyor; and Brunton identifies himself as one of the mechanics of Glasgow to whom he dedicates his work.



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supported by the re-action of a surface, or by the tension of a string perpendicular to the surface. If any point of it hang by a string of given length, it will be confined to the surface of a sphere, and the case will be the same as if it rested on a spherical surface.

55. PROB. IX. *A given beam* PQ *hangs by two strings of given lengths* AP, BQ, *from two given fixed points* A, B: *to find its position when it rests.*

Let AP, BQ meet in g; therefore gG through the center of gravity G is vertical; let this meet AB in E, and let PM, QN be parallel to it; also let QP meet BA in D.

Let $AB=c$, and its inclination to the vertical, $AEG=\epsilon$; $AP=p$, $BQ=q$, $GP=a$, $GQ=b$; $PAB=\alpha$, $QBA=\beta$, $PDA=\delta$. Hence

$$gPQ = APD = PAB - PDA = \alpha - \delta,$$
$$gQP = QBD + QDB = \beta + \delta,$$
$$AgB = PgQ = \pi - (\alpha + \beta);$$
$$\therefore\ Ag = AB\,.\frac{\sin ABg}{\sin AgB} = c\,.\frac{\sin\beta}{\sin(\alpha+\beta)},$$
$$Bg = AB\,.\frac{\sin BAg}{\sin BgA} = c\,.\frac{\sin\alpha}{\sin(\alpha+\beta)};$$
$$\therefore\ Pg = Ag - AP = c\,.\frac{\sin\beta}{\sin(\alpha+\beta)} - p;$$
$$Qg = Bg - BQ = c\,.\frac{\sin\alpha}{\sin(\alpha+\beta)} - q:$$

but

$$Pg = PQ\,.\frac{\sin PQg}{\sin PgQ} = (a+b)\frac{\sin(\beta+\delta)}{\sin(\alpha+\beta)};$$
$$Qg = QP\,.\frac{\sin QPg}{\sin QPg} = (a+b)\frac{\sin(\alpha-\delta)}{\sin(\alpha+\beta)};$$
$$\text{hence } c\,.\frac{\sin\beta}{\sin(\alpha+\beta)} - p = (a+b)\,.\frac{\sin(\beta+\delta)}{\sin(\alpha+\beta)};$$
$$c\,.\frac{\sin\alpha}{\sin(\alpha+\beta)} - q = (a+b)\,.\frac{\sin(\alpha-\delta)}{\sin(\alpha+\beta)};$$

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$$\text{or } c\sin\beta - p\,.\sin(\alpha+\beta) = (a+b)\,.\sin(\beta+\delta)\ \ldots\ldots(1),$$
$$c\sin\alpha - q\,.\sin(\alpha+\beta) = (a+b)\,.\sin(\alpha-\delta)\ \ldots\ldots(2).$$

To obtain α, β, δ, we must have a third equation; for this purpose we must find the tensions of the strings PA, QB; and as these tensions must be equivalent to the weight, which acts in a vertical direction, their components in a horizontal direction must destroy each other.

To find the tension of the string PA, we may suppose the point Q to be a fulcrum on which the beam PQ is sustained by the string PA; hence if we draw Qx and Qy perpendicular on Gg and Ag, we have

$$\frac{\text{tension of } PA}{\text{weight of } PQ} = \frac{Qx}{Qy}:$$

or, if we call the tensions of PA, QB, P, Q, and the weight of PQ, W; we shall have

$$\frac{P}{W} = \frac{Qx}{Qy} = \frac{QG\,.\sin QGx}{QP\,.\sin QPy}:$$
$$= \frac{QG\,.\sin(GDE+GED)}{QP\,.\sin(PAB-PDA)},$$
$$= \frac{b\,.\sin(\delta+\epsilon)}{(a+b)\,.\sin(\alpha-\delta)}.$$

Similarly, we should have

$$\frac{Q}{W} = \frac{a\,.\sin(\delta+\epsilon)}{(a+b)\,.\sin(\beta+\delta)}.$$
$$\text{Hence } \frac{P}{Q} = \frac{b\,.\sin(\beta+\delta)}{a\,.\sin(\alpha-\delta)}.$$

But the forces which draw the beam in the horizontal direction are the resolved parts of these tensions; that is, $P\sin APM$ and $Q\sin BQN$; $\therefore P\sin APM = Q\sin BQN$.

$$\text{But } \sin APM = \sin(AMP+PAM) = \sin(\epsilon+\alpha)$$
$$\sin BQN = \sin(ANQ-QBN) = \sin(\epsilon-\beta);$$
$$\therefore\ P = Q\frac{\sin(\epsilon-\beta)}{\sin(\epsilon+\alpha)};$$
$$\text{hence } \frac{b\sin(\beta+\delta)}{a\sin(\alpha-\delta)} = \frac{\sin(\epsilon-\beta)}{\sin(\epsilon+\alpha)}\ \ldots\ldots\ldots(3).$$

And the three equations (1), (2), (3), will give the three unknown quantities α, β, δ.

Fig.4.1. 'Problem IX' from the sixth edition of Whewell's *Elementary Treatise on Mechanics* (68-69).

class artisans, operatives, mechanics, engineers, or manufacturers? Popular or general texts also vary widely in audience. They seem to exclude the university and practical men, but do little else to define their audience: they could be anywhere from working class men (not involved in the construction or maintenance of machines) to highly educated scientific amateurs to general knowledge-seekers.[66] Many popular texts were re-publications of eighteenth-century works, implying that cutting-edge knowledge was unnecessary to the general reader.[67] The place of publication also varied significantly: academic texts in Cambridge, Edinburgh, and Oxford; general texts in London; practical texts in Birmingham, Glasgow, London, Newcastle, and Edinburgh.[68] This geographical diversity reflects the range of 'mechanics' as a subject as it highlights the differences in the production and consumption of knowledge. This knowledge was not controlled by one geographical area and its constituency (i.e., Oxbridge and elite education, London and elite science and political control, the Northern cities and practical knowledge), but was produced and consumed across a wide geographical—and therefore class, cultural, and educational—spectrum. The

[66] One thing is certain about the intended audience: it was male.
[67] Emerson; J. Ferguson; Robison, *System*.
[68] Surprisingly, I have not yet come across any from Manchester.

mechanisms of distribution also differed, including sale by traditional book-sellers to the elite, purchase by Mechanics' Institutes and Working Man's Libraries, sale to the emerging mass market for printed matter, and assignment by university tutors. Mechanics texts were meant as gateways to elite science, as ways to train the liberally-educated mind, as assistance in practical endeavour, as introductions to natural philosophy, as intellectual memoirs of departed philosophers, and as stepping stones to self-culture and self-help. So although 'mechanics' was a category for our historical actors, it was not necessarily a stable or unified one.

In wider context, 'mechanics' was unstable because contemporary science was itself in flux. Texts on mechanics in the 1820s and 30s were produced within a changing knowledge culture which included an emerging struggle to define and demarcate the purposes and boundaries of science,[69] the incipient professionalization of both science and engineering,[70] the growth of science publishing and the constitution of its audiences,[71] the nascent fission of expert and popular science,[72] the emergence and configuration the *disciplines* of science,[73] and the evolution of 'physics' from 'natural philosophy' into the preeminent among the scientific disciplines.[74] These trajectories were not inevitable; all were contested, incomplete, and chaotic. Mechanics texts reflected the contest and chaos at the beginning of these shifts, especially the differentiation of science from practical questions and the emergence of a science of physics from the primordial soup of natural philosophy. Although far from inexorable, the story of 'mechanics' was one of 'purification' from practical connotations into an elite science. These texts register the moment when 'mechanics', foundational to the emerging discipline of physics, was being constituted as a

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[69] This is a common theme for historians of nineteenth-century science. For important examples, see Gieryn 37-64; Morus, 'Manufacturing' 426-433; Yeo, *Defining*.
[70] On the professionalization of science, see F. Turner, 'Victorian'. On the professionalization of engineering, see Buchanan; Calvert.
[71] Lightman, *Victorian*; Topham, 'Publishing'.
[72] Lightman, *Victorian*; Topham, 'Publishing'; F. Turner, 'Victorian'.
[73] Cahan; Lenoir; Poovey, *Genres*. On the use of 'disciplinarity' in the historiography of science, see Golinksi, *Making* 66-72.
[74] On the shift from 'natural philosophy' to 'science', see Cahan; Knight and Eddy. Several histories of nineteenth-century—or classical—physics have been published from a variety of perspectives: for the development of the central concepts in classical physics and its consolidation of a mechanical view of nature through the concept of energy and the application of mathematics, see Harman, *Energy*; for the struggle to delineate physics from mathematics on the one hand and chemistry on the other between 1780 and 1820, see Heilbron 101-106; for a history which links the development of the concepts of classical physics during the long nineteenth century to industry and technology, see Hunt; for a social history of classical physics that describes its emergence in the early century and accounts for its scientific preeminence by the end of the century according to its institutional development, see Morus, *When*; for a comparative study of the making of physics in the nineteenth century through textbooks and contrasting pedagogical needs, see Simon; for a history of 'energy' in the classical physics of the second half of the century, see Smith, *Science*; for the development of mathematical physics traced through the training provided for it at Cambridge, see Warwick.

pure science. But they also register discordant voices, which drew the lines between practical and theoretical differently and which saw ‘mechanics’ as part of practical rather than theoretical questions. It was a moment when new structures of knowledge were being built; but without a teleological blueprint, they were often shaky, incompatible, and provisional.

Recognized by its authors in the 1820s and 30s, ‘mechanics’ was neither a new genre nor a new subject of study, but its status had changed over time.[75] Early mechanics was a low pursuit that studied the practical and artificial rather than the natural, disqualifying it from natural philosophy.[76] Overcoming the ancients’ disdain for mathematics, the natural philosophers of the Scientific Revolution expanded mathematical study to the universe, seeing it as a machine that could be studied through the same techniques used to study a man-made wedge, pulley, or wheel-and-axle.[77] Still ‘mechanics’ was not identical with ‘mechanical philosophy’. It denoted ‘those Disciplines that consist of the Applications of pure Mathematicks to produce or modifie Motion in inferior Bodies’ according to Robert Boyle.[78] Mechanics had still not lost its practical connotations in the second half of the eighteenth century, as the practical arts of mechanics were not differentiated from the higher pursuits of natural philosophers. Writers on mechanics like James Ferguson, John Robison, and J.T. Desaguliers were natural philosophers but also inventors and instrument makers, who did not divide their interests in practical and what would now be called scientific questions.[79] Robison wrote on mechanics and published in encyclopaedias and philosophical journals. But no matter how theoretical his language, his topic was often practical. Ferguson and Desaguliers both gave immensely popular lecture series on natural philosophy that included substantial considerations of practical, mechanical questions.[80] The lecture format itself depended on machines and instruments to demonstrate the principles or laws of nature the lecturer discussed.[81] This dependence was transferred to the published lectures, which often specifically describe the demonstration apparatus, thereby implicitly including machines in texts on natural philosophy. Thus at the dawn of the nineteenth century, there

[75] Jamieson and Whewell give mechanics a classical pedigree (Jamieson v-vii; Whewell, *First* 1-2).
[76] On the continuance of this situation through the early modern period, see Gabbey; Meli 77.
[77] On transferring knowledge of artefacts onto nature, see P. Harrison, ‘Development’ 17, 21-23.
[78] ‘Usefulness’ 455.
[79] Robison, for example, improved the steam engine while being a lecturer in Edinburgh.
[80] Ferguson’s *Lectures on Select Subjects* was first published in 1760, went through multiple editions, and was republished by both David Brewster beginning in 1805 and by C. F. Partington in 1825. In his preface, Brewster maintained that Ferguson’s *Lectures* was the most read and circulated work on the subject with all classes and that the observer meets ‘with it in the workshop of every mechanic’ (J. Ferguson 1: vii). In his biography of George Stephenson, Samuel Smiles corroborates this view, noting that George and his son Robert learned much of their scientific knowledge from evening study of Ferguson’s *Lectures* (49-50).
[81] Morus, *Frankenstein’s*, ‘Manufacturing’, ‘Worlds’.

was no hard and fast distinction between mechanics, the practical arts, and the high sciences. Instead they were an amorphous, undifferentiated bundle under the title ‘natural philosophy’.

Reflecting the developing trends of differentiation and specialization in the broader knowledge culture of the first few decades of the nineteenth century, several texts on mechanics in the 1820s and 30s began the process of formulating mechanics as a ‘science’, foundational to the new discipline of ‘physics’.[82] Where late eighteenth-century texts had been concerned with actual physical problems in applied mechanics, instrumentation, and measurement, these nineteenth-century texts often by university tutors were concerned with abstract, theoretical, and mathematical problems disentangled from practical application within the demarcated ‘science’ of ‘physics’. Their subject was motion and force rather than simple machines, which they subordinate to principles; they omitted commentary on specific practical application; and they ignored the instruments used to demonstrate the principles they put forward.[83] Thus they formulated a new conception of mechanics as a pure science, delineating it from other aspects of the science of physics and from the practical arts. It was constructed as the foundation of more advanced physics, the intellectual toolkit necessary to understand the cutting edge science of Laplace and La Grange.[84] More broadly, natural philosophers and ‘scientists’ fearing the decline of science and mathematics when made subordinate to practical and industrial concerns, worked hard to divide the theoretical from the applied, science from industry. Leading the campaign, Whewell championed scientific knowledge for its own sake, evident in the mechanics sanitized of practical concerns in his *Elementary Treatise of Mechanics*. In his *Philosophy of the Inductive Sciences* (1840), Whewell divided them thus: ‘Art and Science differ. The object of Science is Knowledge; the objects of Art, are Works. In Art, truth is a means to an end; in Science, it is the only end. Hence the Practical Arts are not to be classed among the Sciences’ (xli).[85]

Yet these theoretical texts on mechanics had only begun the process of purification; it was far from complete. Divergent and dissenting views of mechanics existed at every level. Other texts on mechanics, particularly those written for general and practical audiences, sought to teach mechanical principles that would assist mechanics and engineers in their practical work or allow a general reader to understand the way a machine functioned when he

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[82] On the emergence of ‘physics’ as a discipline in the early nineteenth century, see Morus, *When* 7.
[83] Although the boundaries can be ambiguous, I would include these authors in this group: Bridge; Poisson; Venturoli; Whewell, *Treatise, Elementary, Mechanics*.
[84] The texts which serve as introductions to elite science include: Bridge; Poisson; Venturoli.
[85] Yeo tracks this distinction through Whewell’s work (*Defining*).

looked at it.[86] These texts fulfilled a different view of the value of science put forward by Whewell's good friend J. F. W. Herschel. In his widely read *Preliminary Treatise on the Study of Natural Philosophy* (1831), Herschel emphasized the value of scientific study of nature for its practical applications, arguing that the best art was the product of science: 'Practical Mechanics is, in the most pre-eminent sense, a *scientific art*; and it may be truly asserted, that almost all the great combinations of modern mechanism, and many of its refinements and nicer developments, are creations of pure intellect, grounding its exertion upon a moderate number of very elementary propositions in theoretical mechanics and geometry' (63). Thus, even though practical and scientific knowledge were dividing in this period, mechanics and the texts it titled straddled that divide, some presenting mechanics as a pure science while others stressed the practical applications of its principles. Whewell himself recognized in 1841 that mechanics and mechanism had still not been totally extricated, seeking to do so with Robert Willis in the three works they published between them that year.[87] Yet whether it was pure or applied, mechanics was a science to the authors of these texts, evidenced by their consistent definitions of mechanics as such.[88]

Whether oriented toward knowledge or art, what did it mean for mechanics to be a science? What did it study? What did it mean for something to be scientifically knowable? Whewell and Herschel offered answers to these questions by defining science.[89] In his *Elementary Treatise on Mechanics* (1819), Whewell defined mechanics as '*the science which treats of the motions of bodies, so far as they are governed by discoverable laws*' (3). Mechanics as a science studied the laws which governed phenomena, a view of 'science' reiterated by many. Herschel offers a similar understanding in his *Preliminary Discourse*, seeing principles and the laws of nature, rather than phenomena or facts, as the objects of enquiry (13-14). Honing his definition, Whewell asserts that 'this principle, that *nature acts by general laws*, is the basis of all Philosophy, and the investigation of these laws is the object of Science' (*Elementary* 2).[90]

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[86] Practically-oriented texts include Brunton; Emerson; J. Ferguson; O. Gregory; Hann and Dodds; Hay; Thomas Jackson; Jamieson; Lardner and Kater; Moseley, *Illustrations*, *Treatise*; Robison, *System*; Whewell, *First*; Willis; T. Young.

[87] Through the 1830s, William Whewell and Robert Willis drew and re-drew the boundaries between mechanics, mechanism, and machinery, systematized in Willis's *Principles of Mechanism*, Whewell's *Mechanics of Engineering*, and the sixth edition of Whewell's *An Elementary Treatise on Mechanics*, all published in 1841, see Marsden, 'Progeny'.

[88] Constructing mechanics as scientific pursuit of principles, these texts ignore the practical roots of physics in the nineteenth century. Throughout the nineteenth century, practical and industrial questions, concerns, and values continued to shape British physics, see Hunt.

[89] On Whewell's role, see Yeo, *Defining*.

[90] Also reiterated in his *Astronomy* 3-4.

Both Herschel and Whewell also offered specific, philosophical definitions of the laws of nature, working against the ambiguity created by the term's ubiquity.[91] To Herschel, a 'law' of nature is 'a statement in words of what will happen in such and such proposed general contingencies' (90), or, more abstractly, 'a proposition asserting the mutual connection, or in some cases the entire identity, of two classes of individuals' (101). Acknowledging that law is a metaphor used to understand nature, Whewell defines 'laws of nature' as 'rules for that which *things* are to do and suffer; and this by no consciousness or will of theirs. They are rules describing the mode in which things *do* act; they are invariably obeyed; their transgression is not punished; it is excluded' (*Elementary* 6-7). These laws are pre-programmed into matter, governing how matter acts and reacts.[92] But what did these laws look like in nature or when they were translated into scientific knowledge? Both philosophers connect the knowledge of laws with the perception of the 'regularity', 'uniformity', and 'constancy' of nature's workings.[93] Laws are 'universal and invariable' and 'permanent … consistent, intelligible, and discoverable' (Whewell, *Elementary* 4; Herschel 42).[94] In their highest forms, they are expressed numerically and mathematically.[95] For mechanics to be a 'science', then, it had to trace the universal and regular laws of nature and express them mathematically.

Casting mechanics as a science, its authors indicated what the knowledge of mechanics would look like: knowledge of the laws of nature governing motion and force. The early nineteenth-century genre fulfilled this definition by tracking the uniform laws of nature in the behaviour of matter in motion and under force, which they often called 'mechanical principles' and expressed mathematically in formulas and equations. Nearly all begin with the verbal definition of mechanics and then move on to statements, explanations,and demonstrations of the laws of motion. They use a variety of mathematical approaches, from simple mensuration and arithmetic, to geometry, to algebra and trigonometry, to the latest advances in calculus to express and demonstrate these principles.

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[91] Focusing on its theological implications, Brooke has argued that 'law of nature' was an ambivalent and flexible concept in the nineteenth century, using Whewell and Darwin to contrast sacred and secular conceptions of law ('Natural Law'). Yet despite the theological flexibility of the concept, I think that Herschel and Whewell offer fairly stable and culturally diffused conceptions of the 'laws of nature' as key terms in the methodology of naturalistic explanation

[92] Herschel 36-42; Whewell, *Elementary* 7, 210.

[93] Herschel 39-42; Whewell, *Elementary* 3-4.

[94] The conception of the laws of nature as the program of the universe is made more explicit by Charles Babbage in his *Ninth Bridgewater Treatise* where he compares the running of the world according to laws to the running of his calculating engine, a prototype computer, according to the rules with which he programs it. Laws as the software of the universe have been a powerful metaphor in twentieth-century philosophy of science, but have recently been critiqued by Mauro Dorato in *The Software of the Universe* (2005).

[95] Herschel 123; Whewell, *Elementary* 8.

Owing to the importance of the University's mathematics tripos, the texts written by Cambridge University tutors assume a huge amount of mathematical knowledge and proficiency of their readers to understand their demonstrations of the principles of mechanics (Fig. 4.1). Texts written for practical men were still built on quantification and maths, but were simpler, often including tables of measurement, conversions, multiplication, and simple equations. Brunton's *Compendium* serves as an introduction to the maths necessary for practical application. In his *Mechanics*, Jamieson presents every mechanical principle in verbal description, drawing on the reader's experience, then explains it through a geometrical diagram, and finally translates it into an algebraic equation. At the end of each treatise, he includes a table of all the useful equations he has introduced (Fig. 4.2). Thus mathematics was essential to mechanics—and essential to the physics built upon it.[96] Its centrality to the Cambridge liberal arts education in order to discipline and shape the minds of students raised mathematics to a respected position.[97] The importance of mathematics to mechanics texts thus raised the public profile of mechanics as it became abstract, general, and theoretical.

Formulated as a theoretical science but historically rooted in the practical arts, 'mechanics' had a changing and contested relationship to actual machines. Mechanics textbooks were a site where the boundaries between science and technology, nature and machine were drawn, challenged, and re-drawn. Theoretical texts tried to purify mechanics of its practical roots while practical texts insisted on the importance of machines to mechanics and of mechanics to machines. Yet the ambivalence of the word 'mechanics' and its association with mechanical occupations allowed 'mechanics' to construct meanings of machines.[98] Machines were present in all types of mechanics texts in three basic ways: 1) the 'mechanical powers', the name given to simple machines, are described and discussed in terms of either motion or force, 2) contemporary machines serve as examples of principles which have just been explained, or 3) the design and contrivance of machines are presented as the object of knowing mechanical principles.[99] Theoretical texts devote the majority of

[96] For the increasing fusion of mathematics with physics, see Warwick.
[97] On the practical associations of mathematics, see Heilbron; on the association of mathematics with mind-formation through the Cambridge tripos, see Warwick.
[98] Outside its specific 'scientific' meaning, 'mechanic' and 'mechanics' were polysemous terms in the early nineteenth century. 'Mechanic' could be used as a synonym of 'mechanical' while 'mechanics' could also refer to the men who worked on or with machines. Marsden discusses the variety of 'resonances' of 'mechanism', a close linguistic cousin, in this period ('Progeny' 409-412).
[99] Whewell's *Elementary Treatise* is an example of the first, Moseley's *Illustrations of Mechanics* of the second, and Hay's *Concise System of Mechanics* of the third. Although the uses are often blended in a single text, one is often more used than another, linked to the purpose of the text: the first with mechanics as foundation for advanced physics, the second with mechanics for popular audiences, and the third with mechanics as education for engineers and mechanics.

OF THE CENTRE OF GRAVITY. 127

Nature of the figure.	Form of the Equations.	Pages where found.	Particular Remarks and conditions of the data.
Triangular figures.	$AH=\frac{1}{3}\sqrt{2(d^2+\delta'^2)-\delta^2}$ . . $BH=\frac{1}{3}\sqrt{2(d^2+d^2)-\delta'^2}$ . . $CH=\frac{1}{3}\sqrt{2(\delta^2+\delta'^2)-\delta^2}$.	51	d, δ and δ' the sides of the triangle, and AH, BH and CH, the distances of A, B and C from the centre of gravity.
Triangular figures.	$AD=\frac{1}{2}\sqrt{2(d^2+\delta'^2)-\delta^2}$ . . $BF=\frac{1}{2}\sqrt{2(d^2+\delta^2)-\delta'^2}$ . . $CE=\frac{1}{2}\sqrt{2(\delta^2+\delta'^2)-d^2}$ . .	51	a, c and δ' the sides of the triangle; AD, BF and CE the distances from the angular points to the middle of the opposite sides.
	$d=\sqrt{2(AH^2+BH^2)-CH^2}$ . . $\delta=\sqrt{2(BH^2+CH^2)-AH^2}$ . . $\delta'=\sqrt{2(AH^2+CH^2)-BH^2}$ . .	54	Particulars as above.
	$d^2+\delta^2+\delta'^2=3(AH^2+BH^2+CH^2)$ . .	55	
Quadrilateral figures.	$pH\,(2AD+BC)=nH\,(2BC+AD)$ . . .	67	AD and BC parallel sides of the figure d, δ and δ' as referred to in the text, (see the diagram p. 66 and the description p. 68.)
	$nH=\dfrac{(2AD+BC)\sqrt{2(d^2+\delta^2)-\delta'^2}}{6(AD+BC)}$. $pH=\dfrac{2BC+AD\sqrt{2(d^2+\delta^2)-\delta'_2}}{6(AD+BC)}$.	68	
Figure in the form of a trapezoid.	$nH=\dfrac{(2AD+BC)\sqrt{4d^2-\delta'^2}}{6(AD+BC)}$ . . $pH=\dfrac{(2BC+AD)\sqrt{4d^2-\delta'^2}}{6(AD+BC)}$ . .	71	Particulars as stated above.

Fig. 4.2. Equations from Jamieson's *Mechanics for Practical Men* (127).

their pages to principles, definitions, formulas, and mathematical expressions of mechanics, yet they do integrate the 'mechanical powers' as they call the simple machines of the lever, wheel-and-axle, pulley, inclined plane, screw, and wedge.[100] These sanitized simple machines are generalized, idealized, and abstract, removed from any actual mechanical examples and discussed in terms of the mechanical principles which govern their behaviour. Once purified, mechanics could be turned around to help readers understand the new technologies. The more practical texts include often longer discussions of the mechanical powers, but they also nest them within discussions of the principles of mechanics.[101] Many authors intend the principles they introduce to be applied practically. Jamieson, for example, saw his work as 'a manual of principles' which included 'practical rule[s]' for engineers and mechanics, a sentiment shared by Hay.[102] These principles were not just constructions of the human mind, but the laws of nature. Indeed, from the perspective of mechanics, there was no distinction between nature and machine. For, as Moseley admits, his 'illustrations of the mechanical properties of matter and the laws of force are drawn *promiscuously* and almost equally from ART and NATURE' (*Illustrations* ix), because they obey the same laws.[103]

In subordinating machines to principles, both theoretical and practical mechanics texts constructed machines as governed by knowable principles. The rational human mind knows machines through the mathematics used to describe their idealized actions. Mathematics enables the prediction of what will happen when an object encounters another object or force, ultimately allowing the description and prediction of the motions and forces of complex machines like steam engines whose power output could now be calculated. Dovetailing with the intelligible language of machines from my second chapter and the classification of machines from my third chapter, mathematical mechanics triumphantly presented machines

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[100] These discussions can be found in the theoretical texts here: Bridge 227-300; Emerson 26-38; J. Ferguson 53-80; Thomas Jackson 58-101; Walker 35-55; Whewell, *Elementary* 136-156, *Treatise* 257-342, *Mechanics* 2-24.

[101] These discussions can be found in practical texts at these places: Brunton 44-53; Hay 29-46; Hann and Dodds 11-41; O. Gregory 1: 70-106; Lardner and Kater 160-223; Moseley, *Treatise* 63-123; Venturoli, *Theory* 109-167. A few authors omit them altogether, including Moseley, *Illustrations*; Poisson; and Robison, *System*. Some blend them in without giving them dedicated treatments, including Whewell, *First*; Willis; and the author of the Library of Useful Knowledge's 'Mechanics'.

[102] Jamieson x; Hay v.

[103] Herschel writes a similar philosophy of technology into his *Preliminary Treatise*, suggesting that the practical arts depend on knowledge of the laws of nature (43-45, 54-55). The blurring of nature and machine in texts on mechanics is continuous with the naturalization of machines accomplished by natural histories of machines and industrial travel narratives discussed in chapter three. On collapsing distinctions between machines and nature in exhibition rather than textual spaces, see Morus, 'Manufacturing' 426-433.

re-packaged as part of science. And as subjects of science, their motion could be predicted, and therefore controlled.[104] Through math, the mind had mastered the machine.

While these texts implicitly increased man's agency in the industrial world through man's rational knowledge of the laws of mechanics, they also downplayed the autonomy of machines, presenting them as merely transferring or manipulating power they did not create and giving them a specific place in human control of nature. In contrast to critiques of the factory system which make machines into a looming and all-pervasive threat, texts on mechanics begin to cut machines down to size by subsuming them into the study of force and motion. Machines only play out the universal system of the laws of nature. Focusing on force and the resolution of forces (occasionally motion and the resolution of motions), texts on mechanics present machines as the passive recipients of force rather than its source.[105] An overwhelming majority define machines merely as objects which transfer or transform already present motions, velocities, or forces into more useful forms.[106] For example, Moseley defines a machine as 'an assemblage of parts destined to receive the operation of an agent, and to transmit it to the point where it is to be applied, modifying it in the transmission, according to the circumstances under which it is to be applied' (*Illustrations* 363). Although only discussed in practical texts, these agencies are the natural ones of water, steam, and animal motive power.[107] The machine is not an agent or prime mover, but just a tool which allows humans to control the agencies of nature to meet human needs. As Herschel concludes in his *Preliminary Treatise*, 'such are the forces which natures lends us for the accomplishment of our purposes, and which it is the province of practical Mechanics to teach us to combine and apply in the most advantageous manner; without which the mere command of power would amount to nothing' (63).[108] By turning to force, these texts present machines as neutral and passive transfer points for other agents, draining them of the

[104] The scientizing of machines was not without contest, reflected in debates over engineering education. Many believed that engineering had more to do with the 'rule of thumb' than with scientific 'laws of nature'. A helpful introduction to the historiography of the relationship of science and technology in the nineteenth century is found in Wegenroth. For an account of a successful rhetorical integration of science into engineering education, of the theoretical and the practical, in the late nineteenth century, see Marsden, 'Engineering'. For 'rule of thumb' versus science, see Gooday, 'Precision' 43-49. On the complex reception of academic engineering courses from the 1830s and 40s onward, see Marsden and Smith 227-238.
[105] On the presentation of machines in terms of force beyond texts on mechanics, see Ketabgian 107-146.
[106] The definitions of machines or mechanical powers in terms of the work they do can be found in Emerson 2; J. Ferguson 55; Hay 43; Hann and Dodds 1; Venturoli, *Practical* 164-166; Whewell, *Elementary* 139; T. Young 1: 203. For the definitions of machines in terms of the transfer and transformation of force or motion, see Bridge 1: 227; Brunton 96-97; O. Gregory 1: 70, 2: 1; Thomas Jackson 58-59; Lardner and Kater 160; Walker 35; Whewell, *First*, *Mechanics* 2; Willis xiii.
[107] For example, see Moseley, *Illustrations* 369-383. Even outside the disciplines of physics and mechanics, this principle was recognized, see Roget 1: 124.
[108] Others agree, see Baines 10.

autonomy attributed them by critics of the factory system. Machines thus fit squarely into the Baconian project of mastery over nature. Indeed, as Lord Jeffrey exulted in 1819, the steam engine has ‘completed the dominion of mind over the most refractory qualities of matter’ (176)—mastery built on knowledge of the laws of nature, expressed mathematically and applied to machines.[109]

The mathematization of machines achieved in early nineteenth-century texts on mechanics triangulated the three concepts that have been jostling against each other in this chapter: human agency, the laws of nature, and machines. Intervening in the larger question of the relationship between humans and machines, texts on mechanics unwittingly drew on contemporary anti-industrial conceptions of human agency as including both active and rational elements. Yet mechanics texts privileged the rationality of human agency. Against the opposition of machine to mind set up by critics of the factory system, mechanics texts put the human mind in control of machines through rational knowledge of the laws of nature. The external dimension of agency was evidenced by effects rather than by causes—by the human’s ability to get machines to do things. While machines seem to work with no human intervention, these texts establish a relationship between them: machines may seem self-acting, but they require the rationality of their inventors, keepers, and observers. At the same time, they presented machines as passive. This had two larger philosophical and cultural ramifications. First, while machines worked by natural laws, they were entirely dependent on some other power both to create them and to put them into action. They were not self-acting. Second, with the mastery of mind over machine through science, the machine could also come to symbolize the control of mind over matter—and to point to the necessity of a creating mind behind all matter.

Natural Theology: An Active God in a Law-bound World

The recapturing of matter by mind through the science of mechanics had results far beyond solving the ‘problematic of mechanism’, the problem of human agency in a seemingly autonomous industrial world. The solution industrial apologists offered for the human agency problem had important consequences for theology—natural theology in

[109] Historian of the factory system, Richard Guest, agreed, calling the steam engine one of the highest ‘triumphs of the mind’ (5) which has ‘subjected to Man a Giant, by whose assistance he can obtain the treasures of mines hitherto unapproachable by reason of subterraneous waters—draw ponderous loads of fuel, limestone or other substances, along rail ways without the help of beasts—set in motion machinery, to which mere human strength was unequal—cross the seas independent, and even in despite of winds and tides, and with a rapidity before unknown’ (4).

particular. Natural theology faced an agency/autonomy problem parallel to the industrial one: just as the machine's autonomy seemingly opposed human agency, God's agency was threatened by a seemingly autonomous natural world governed by laws. Although this theological problem was precipitated by the contemporary expansion of naturalistic explanation, it also had deep historical roots in the anthropomorphism of natural theology, which bound the industrial and theological problems tightly together. Inherently anthropomorphic, the design argument understands God and his relationship to his creation in terms of the human and its relationship to what it creates. When humanity's relationship to its creations are contested, God's relationship to his creation is also subtly contested. Thus the industrial problem informed the theological one, but so did its solution.

While often dismissed out-of-hand as philosophically naive, the Bridgewater Treatises actually offered sophisticated yet indirect resolutions to the problem of divine agency in a law-governed natural world. Whether implicitly or explicitly, they incorporate the laws of nature into their apologia, using them either as their primary evidence or acknowledging their functioning in the natural world they describe. Focusing on the natural rather than the supernatural, these texts accommodate God's action into an increasingly naturalistic vision of the universe, becoming a nascent philosophy of science and of the laws of nature. Simultaneously positing a law-bound world and an active Divine mind governing that world, they assimilate law with divine action by drawing on reservoirs of meaning human agency had acquired in contemporaneous discussions of machinery, mechanics, and the factory system. Building on industrial apologia's emphasis on rationality in human agency, natural theology maintained God's agency in a law-governed world by emphasizing his mind and its relation to laws. Ultimately, humanity's growing confidence in its mind-enabled ascendancy over nature and machines helped to ease the theological problem of law.

Scholarly skim readings of nineteenth-century natural theology characterize it as miraculous rather than naturalistic.[110] But in *The Ninth Bridgewater Treatise*, his unauthorized, unfunded, and combative addendum to the series at its completion in 1837, Charles Babbage complained that the sponsored authors actually ignored miracles. Indeed, that only one of them mentions them—once (vi). Despite alarms raised both by religious critics of science and by natural theologians in the 1830s that the study of laws and second causes in nature was risky religious business, the writers of natural theology in the 1830s,

[110] On natural theology as miraculous, see Ellegård 141; Mason and Knight 155, 157. Relatedly, many scholars conceive of law as inherently opposed to natural theology, see Ellegård 102; Ghiselin; Ospovat, 'Perfect'.

respected scientific men, consistently assumed a law-governed universe, some even making those laws the primary content of their natural theology.[111]

Modulated by the specific concerns of their scientific disciplines, the Bridgewater authors consistently presented a uniform and regular rather than miraculous natural world, echoing Herschel and Whewell's terminology and conceptions of nature and its laws.[112] 'Unity' and 'uniformity' are favourite key words in discussions of design in anatomy and physiology: Buckland traces the 'Unity' (1: 370) of the 'principles of construction' (1: 306) in animals through the geological epochs, Kirby remarks the 'general analogy of creation' and uses analogy to connect different biological forms (1: 147), Bell notices the synchronic homologies in the structures of the hand throughout the animal kingdom, and Roget perceives the 'unity of composition' (2: 627) throughout the living world.[113] In geology, Buckland veers from his early catastrophism to insist that the same laws and processes have been functioning throughout time to produce geological changes (1: 34-50).[114] More generally, the authors also notice the regular connection of cause and effect (Roget 1: 6; Bell 263) and the 'undeviating steadiness and regularity' (Whewell, *Astronomy* 4) and 'certainty and regularity of nature' (Kidd 343) and its laws. More complexly, the unity of nature and knowledge about it is implied in the structure of several works: Kidd compares the natural history of Aristotle and Cuvier to reveal their point-by-point similarity to demonstrate the 'uniformity of the laws of nature' (348); Prout organizes his otherwise diverse treatise on chemistry, meteorology, and digestion around the operations of the laws of heat and light, emphasizing the 'analogy

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[111] On the selection of authors of good scientific reputation and the 'high merit' of the Bridgewater Treatises as scientific textbooks, see Brock 173-174. Scholars have recognized their contextual scientific merit: for example, Ospovat treats the works by Bell and Roget as important treatises on physiology ('Perfect') while Blaisdell treats Kirby's as a major contribution to entomology.

For scholarship sensitive to the integration of the laws of nature into nineteenth-century natural theology, see Brooke, 'Natural Theology of the Geologists'; Lightman, 'Victorian'; Topham, 'Teleology'.

[112] On natural theology's responsiveness to science, see Brooke, 'Natural Theology and the Plurality', 'Religious Apologetics', 'Why'; Gascoigne 231-234; Topham, 'Biology'.

[113] These natural theological naturalists here flirt with the dangerous French physiology of Geoffrey St. Hilaire whose proposal of the 'unity of composition' in biological forms was used to support Lamarckian transmutation theories. While the 'unity of composition' theory could suggest that all current animals descended from common ancestors, these natural theologians use it to argue for a divine designer. Yet the danger of this theory was neutralized by presenting it within the structure of the evolution-denying, natural theology-friendly physiology of Georges Cuvier which was based on function rather than form (only Roget assimilates St. Hilaire). This 'unity of composition' physiology was developed into a natural theology based on 'archetypes' in the 1840s by the British naturalist Richard Owen. On the assimilation—and transformation—of the physiologies and zoologies of Cuvier, St. Hilaire, and W. S. Macleay into natural theology, see Blaisdell; Brooke, 'Scientific'; Topham, 'Biology'. On the struggle between St. Hilaire's and Cuvier's physiologies among British naturalists in the mid-nineteenth century, see Ospovat, 'Perfect' 35-39. On the shift from Cuvierian teleological explanation to naturalistic explanation in biological natural theology in the 1830s and 1840s, see Ospovat, *Development* 6.

[114] On Buckland's shift from catastrophism to Lyellian uniformitarianism, see Greene; Klaver 101. On the place of Buckland's Bridgewater Treatise in British geology and culture, see Klaver 87-101; Rupke; Topham, 'Beyond'.

that prevails throughout the whole' (83); and Bridgewater-outsider Powell draws examples from geology, physiology, and astronomy and physics, suggesting that all the sciences can demonstrate the same points about God.[115] Indeed, for Whewell, the unity of all knowledge, essential to his philosophy and to his natural theology, was of a piece with the unity and uniformity of nature.[116]

While the regularity and unity of nature stressed by all of the authors indicates that the laws of nature were both the assumption and methodology of their science, only some of the natural theologians of the 1830s made those laws their direct, primary evidence, including Whewell, Prout, Roget, Buckland (in his geological dynamics section), and Powell.[117] Whewell traces the workings of laws in different domains, organic and inorganic, and argues that the adaptation of these unrelated laws points to the divine. Prout's method is to discover the laws of chemistry and then trace them in the workings of the weather and digestion. Roget argues from the laws of uniformity in physiology. Finally, Powell sees the order and arrangement of laws as the best—and neglected—evidence of God (x) for 'the more closely and accurately the phenomena are scrutinized and reduced under general laws, the more powerful is the weight of evidence' of design (2-3). Thus these authors take up the contemporary understanding of science as at least describing and often explaining all through 'the great laws of nature' (Laplace 3), for nature, according to Whewell, is 'a collection of facts governed by laws: our knowledge of nature is our knowledge of laws; of laws of operation and connexion, of laws of succession and co-existence, among the various elements and appearances around us' (*Astronomy* 3). Babbage's complaint about the Bridgewater Treatises could not be more right: they highlight *the natural*, not the supernatural. The question of divine intervention seems irrelevant to a series focused on demonstrating the regularity and unity of nature through the sheer profusion of natural detail it incorporates. In the terms of chapter two, they concentrated on the explainable rather than the inexplicable, the intelligible rather than the sublime or mysterious.

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[115] The conception of nature as unified resonated with the emergent thermodynamical theory in physics of the correlation of physical forces—of the idea that everything in nature is unified and connected through its capacity to be converted into something else through physical or chemical processes.

[116] On the unities of nature and knowledge for Whewell, see Yeo, 'William'; on the unity of scientific knowledge for Whewell—and responses to it, see Yeo, *Defining* 231-255. Indeed, Whewell's concept of 'consilience' introduced in his *Philosophy of the Inductive Sciences* (1840), although critiqued by J.S. Mill, has been resurrected by Humanist biologist E. O. Wilson in his highly-influential *Consilience: The Unity of Knowledge* (1998).

[117] On law as primary evidence, see chapter two. On the shift from contrivance natural theology to law natural theology through adaptation, see chapter three. For an account of this shift and of its intellectual exigencies between the 1830s and 70s, see Corsi.

While the Bridgewater authors adopted naturalistic explanation in their methodology, they denied naturalism in their metaphysics.[118] They consistently emphasized a God that is present, powerful, and *active*. Although early nineteenth-century natural theology often functioned as popular science, it also had a fundamental religious purpose.[119] Yet this function was often not primarily apologetic, but devotional.[120] The Bridgewater Treatises were liberally sprinkled with devotional, homiletic, and Biblical language avowing a present and active God.[121] The designer of the natural world is described as a 'ruling' (Bell 1), 'controlling' (Buckland 1: 361), 'forming and presiding' (Chalmers 1: 9), 'creating and presiding' (Whewell, *Astronomy* 1), 'a harmonizing, a preserving, a contriving, an intending' (14) power. This is not an absentee watchmaker, but an attentive and involved Deity. In keeping with natural theology's method of identifying God as the originator of the universe, they also insisted on his continued interaction with it in their relational, descriptive nouns for him. He is the 'Creator, Governor, and Preserver' (Whewell, *Astronomy* 2); the father, teacher, lawgiver, and moral governor (Chalmers 2: 61); 'the Maker and the Ruler' (1: 74); and the 'Preserver and Governor' (2: 48) of the universe. Belying naturalism, they echoed the declaration in Acts 17.28 that in God 'we live, and move, and have our being' (*KJV*).

These echoes of the doctrine of divine action are occasionally affirmed by more substantial theological statements and by specific natural historical examples. For Whewell, God is 'eternal and omnipresent, conscious of all relations, and of all the objects of the universe, instituting laws founded on the contemplation of those relations, and carrying these laws into effect by his immediate agency' (*Astronomy* 366), while for Prout 'He directs the universe, at the same time takes cognizance and regulates the movements of every individual atom in it' (172). Chalmers insists on the voluntaristic freedom of God's creativity and will while Kirby takes the occasionalist position that God's continued action and support is

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[118] Methodological naturalism appeals to secondary causes to explain phenomena but without committing to the hard claim made by metaphysical naturalism that there are no primary causes. I was introduced to this distinction by Numbers, who notices that the historical triumph of scientific naturalism was often born along by Christian methodological naturalists who would deny metaphysical naturalism, see Numbers, 'Science'.

[119] On natural theology as popular science, see Brooke, 'Religious Apologetics'; Fyfe, 'Publishing', *Science*; Lightman, *Victorian* 39-49, 'Victorian' 355-362; Topham, 'Science and Popular'. On natural theology as a narrative technique of late nineteenth-century popular science, see Lightman, *Victorian*. On natural theology as an apologia for science, see Brooke and Cantor 153-156. On natural theology as the foundation for popular science narratives and as yielding to a narrative of natural history later in the century, see Lightman, 'Story'.

[120] On natural theology's devotional function, see Astore; Brooke, 'Indications'; Fyfe, *Science*; O'Flaherty, 'Part 1'.

[121] On the audience as Christian, see Kidd ix-x; Whewell, *Astronomy* vi; J. Robson 93-97. On the language and rhetoric of natural theology, see Brooke and Cantor 176-206; Eddy, 'Rhetoric'; Emblen; Lightman, 'Visual'; J. Robson; Zeitz.

necessary to the continued existence of the universe.[122] Life itself, as distinct from organization, serves as the example of this continued action and superintendence. Many of the natural theologians of the 1830s, allowing a world much older than 6000 years which had undergone significant geological changes, insist that direct divine intervention at those changes is necessary to account for the emergence of new life forms for each of those ages while others allow the workings of law to explain some of the changes, but continued to invoke divine agency and creativity.[123] At heart, they all agree with Buckland that such adjustments 'could only have originated in the will and intention of the Creator' (1: 310).

Thus the Bridgewater Treatises present seemingly contradictory views of the world. On the one hand, in their methodology they fall into the naturalist camp by emphasizing the regularity and lawfulness of the material world and by filling twelve volumes (eight titles) with example-after-example of material objects and processes in nature. On the other hand, in their metaphysics they are staunchly supernaturalist, insisting on God's activity begun at the origin and continued ever since. So how did these two conceptions—of the universe as law-bound and of God as active—fit together? Is their conjunction to be understood as a mystical, a-rational assertion of contradictory worldviews? Or is it logically possible to have God and naturalistic explanation? Margaret Osler has suggested that the 'roots of European intellectual life' is in answering these questions, in reconciling the Biblical view of God's power and will with the Greek emphasis on the orderliness of nature that does not require intervention (*Reconfiguring* 1-2). The statements of and solutions for this enduring problem have varied over time, place, and culture. In British natural theology of 1820s and 30s, the answer was partly in its expressed philosophy of laws and partly in contemporary conceptions of humanness and human action—and in the conjunction of the two.

Inherently anthropomorphic, natural theology assimilated an active God and the uniform workings of the laws of nature by drawing on the Cartesian dualism posited in contemporary interpretations of the encounter between humans and machines.[124] Industrial

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[122] Kirby xc-xci; Chalmers 1: 53-54. On Chalmers and the contingency of the laws of nature, see C. Smith, *Science* 17-22. On Chalmers and voluntarism, see C. Smith, 'From'.

[123] For those positing intervention, see Buckland 1: 58-59, 395, 585-86; Bell 2, 39-41, 263; Chalmers 1: 28-29. For those appealing to law, see Prout 166-167, 179-180; Roget 1: 54-57. Although this solution to the problem of new and well-adapted species in new geological epochs seems to violate naturalistic explanation, Cannon has argued that it was the most rational explanation for those writing in the 1830s, with all other solutions being perceived as wild speculations.

[124] Only a truly negative, or apophatic, theology can hope to avoid this charge. Any positive, or cataphatic, theology must acknowledge—and often embraces—the centrality of the human to understanding God, whether in its philosophy, methodology, or psychology. The anthropomorphism of natural theology was recognized and critiqued in its own time, for example in Robert Browning's 'Caliban upon Setebos' (1864). For a simple summary of Browning's critique, see Peterfreund; for a more sophisticated view, see Loesberg.

apologists maintained human agency by emphasizing mind over matter, by emphasizing the rational mind's power over both its own body and over other material objects. This lined up with the inherited and inherent dualism of natural theology, which had long maintained dualisms between creation/God, natural/supernatural, and matter/mind.[125] The problem for natural theology came when the conception of the natural began to preclude the supernatural, when matter was conceived in such a way that God was irrelevant or impossible. Resonating with industrial Cartesian dualism, natural theology answered this challenge by absorbing and re-deploying the pro-industrial valences of human agency onto God's agency: mind controlled matter through rational knowledge, through the presence of mind behind and beyond matter.

Natural theology exalted and examined human rationality because it implicitly relied on human reason's ability to ascertain some knowledge of God, bolstering and expanding the definition of humans as rational agents.[126] The human-as-rational-agent was the particular flavour of nineteenth-century natural theological anthropomorphism: the Bridgewater Treatises consistently infer or assume a divine 'Intelligence' or 'Mind' behind the universe. Drawing on the human manipulation of matter, these references often related to *telos* in nature. For example, Roget asserts that laws connecting means and ends

> involved the operations of mind, in conjunction with those of matter. They pre-suppose intention or design; a supposition which implies intelligence, thought, motive, volition, — particular purposes to be answered, requiring the agency of powers and of instruments adapted to the production of the intended effects; — the knowledge of the properties of matter, the selection and choice of particular means, and the power of employing them in an effective manner. (1: 22-23)

But these references to mind could also relate to *laws* of nature: Whewell, for example, observes that it is a universal conviction that law implies mind (*Astronomy* 293-303). Emphasizing mind meant that law could be subsumed into *telos*, as the regularity and law-bound quality of nature served a purpose.[127] Yet the association of intelligence with intention

[125] The Bridgewater Treatises carefully corroborated mind-body dualism by insisting on the mind's independence from matter: see Bell 5, 207-208; Chalmers 1: 37; Kidd 1-79; Prout 411-412; Roget 2:508-509.
[126] On the epistemological discussions and engagements of natural theology in the 1820s and 1830s, see Corsi 147-148; Lightman, 'Visual' 655-657; Yeo, *Defining* 248-249, 'William'.
[127] While Ospovat opposed teleology and law as ways to understand nineteenth-century natural history (*Development*; 'Perfect'), Topham has traced their compatibility ('Teleology') and Brooke sees designed laws as just one of four types of teleological argument in the nineteenth century ('Between'). Topham can even suggest that Whewell presents a 'naturalistic teleological argument' ('Teleology' 151). Ospovat does see a

only requires a mind acting at the originary moment of creation, a view perilously close to deism. But the contextual anthropomorphic resonance of intelligence with agency also suggested the continued activity of the divine mind. This significance of intelligence is evident in Buckland's work, in which the uniformity of nature was only explainable through reference to 'the agency of one and the same Creative intelligence' (1: 414). Thus, these texts directly combine an active divine mind with a regular, law-bound universe.[128]

Yet law and continued divine activity were well-nigh impossible to assimilate philosophically in a climate of increasing scientific naturalism compounded by the Humean definition of miracles as law-violations. How could law and an active divine mind be harmonized? Setting aside a philosophical solution, an anthropomorphic one emerged. While the contested relationship between humans and machines threatened to undermine natural theology, the resonance of the industrial debate with the theological one created points of contact between the two discourses which stabilized their relationship. Theologically, a law-governed world whose effects could be traced naturalistically to physical causes became an autonomous world which excluded or denied the continued agency of its creator. In the culture of technology, the agency of *Homo faber* was threatened by the increasing autonomy of its handiwork—the machine. While both tensions register fear that the mind behind the matter will be lost, law threatened divine agency while it was the key to recovered industrial human agency. But in resurrecting human agency through knowledge of 'law', the culture of technology re-wrote the relationship between law and mind, allowing active mental agents to coexist with laws and providing an anthropomorphic solution to the theological problem.

Early Victorian texts on mechanics implicitly link knowledge of the laws of nature with human agency in two ways. First, they connect the invention of a machine with the knowledge of laws or principles by inventors. In doing so, they implicitly constructed the great innovators of the Industrial Revolution as *knowers* as much as *doers*. Here the human mind manipulates matter through its knowledge of laws to meet its own needs. As Herschel

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higher conception of teleology by law with scientists like Darwin in the 1830s, but *not* in the Bridgewater Treatises (*Development* 29-37).

[128] In doing so, they simultaneously contradict and hijack 'Laplace's demon', an expression of determinism through the imagination of an all-knowing yet passive mind, expressed in *A Philosophical Essay on Probabilities* (1819):

> We ought then to regard the present state of the universe as the effect of its anterior state and as the cause of the one which is to follow. Given for one instant an intelligence which could comprehend all the forces by which nature is animated and the respective situations of the beings who compose it—an intelligence sufficiently vast to submit these data to analysis—it would embrace in the same formula the movements of the greatest bodies of the universe and those of the lightest atom; for it, nothing would be uncertain and the future, as the past, would be present to its eyes. (Laplace 4)

claimed, 'almost all the great combinations of modern mechanism, and many of its refinements and nicer developments, are creations of pure intellect, grounding its exertion upon a moderate number of very elementary propositions in theoretical mechanics and geometry' (63).[129] This kind of mind-driven agency is the kind attributed to God-the-Creator. The natural theologians of the 1830s constantly reiterate this point when they talk about physiological contrivances, especially their favourites—the eye and the ear.[130] Both of these organs work perfectly according to the laws of light and sound, but did not originate in those laws. Deploying his usual rhetorical questions, Whewell asks

> is it by chance that the air and the ear exist together? Did the air produce the organization of the ear? Or, the ear, independently organised, anticipate the constitution of the atmosphere? Or is not the only intelligible account of the matter, this, that one was made for the other: that there is a mutual adaptation produced by an Intelligence which was acquainted with the properties of both; which adjusted them to each other as we find them adjusted. (*Astronomy* 123-124)

Yet this only guarantees obvious action at the moment of invention, not in all the moments afterwards.

But the second link forged by texts on mechanics between law and mind does guarantee the maker's action in the continued functioning of his invention. Intervening in the debate about human agency in the technological world, they offered anyone agency through knowledge. Debunking the autonomy of machines, they made human control of machines possible through knowledge. While few people invented steam engines or watches, texts on mechanics allow the contemporaneous observer at any moment in time to understand how a machine works, to reverse engineer the machine down to its primary guiding principles.[131] And with the Baconian-Victorian conviction that knowledge is power, knowledge of the machine and its laws was power—agency—for the observer. Thus texts on mechanics gave humans agency in their encounters with machines both at the moment of invention and at contemporaneous interactions with pre-existing objects through knowledge of laws. This is a sustained, instrumental, Cartesian dualism in which an object can be manipulated at any time without violating the laws of nature or breaking the machine. Natural theology implicitly

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[129] Andrew Ure agreed (*Cotton* 1: 172).
[130] On the importance of the eye, see Lightman, 'Visual'.
[131] This goal of giving observers (rather than makers) knowledge of machines also corrected natural theological anxieties about whether Paley's 'unmechanical looker-on' would be able to see design if unsure of how something worked (Paley 52-53; Prout 9-10).

adopted this understanding of the relationship between humans and laws. In talking about the eye (the prime example of natural mechanism), Chalmers says that humans 'can take cognizance of any visible thing, in virtue of the power which he has over the eye of his body—a power not to alter the laws of vision, but to bring the organ of vision within the operation of these laws' (1: 252-253). Enabled by rationality, human agents work with the laws of nature, not against them. Anthropomorphically, this synthesis of mind and law could intuitively, if not logically make the conjunction of law and active divine mind in natural theology plausible. God was present and active in laws not by contravening them but by knowing them, being both their Creator and continued knower. Indeed, Whewell even calls the 'Divine Mind … the seat of those laws of nature which we have discovered' (*Astronomy* 379).[132]

While an anthropomorphism built on humans as technology-wielding agents made possible the assimilation of an active God with law-bound nature, mechanical metaphors were ironically also used to articulate the limits of anthropomorphism.[133] Whewell, Chalmers, and Babbage fear that understanding of God is restricted if based only on the human manipulation of matter.[134] For Whewell and Chalmers, divine and human designers differ when they create or invent: humans merely *use* what already exists in nature, including both laws and matter, but God *creates* laws and matter and then arranges them as he wills.[135] Human inventors in the early nineteenth century were slowly beginning to recognise certain limits: they had failed to create either life or a perpetual motion machine.[136] But God, according to the natural theologians, chose to make whatever he willed, untrammelled by necessity or givens.

[132] On idealism and nineteenth-century natural theology, see Bowler, 'Darwinism'; D. Cohen; Fisch, *William*; Gillespie, *Charles* 68-69, 'Divine' 214-215, 228; Snyder, 'It's'; Topham, 'Biology' 107; F. Turner, 'Victorian' 361; Yeo, 'William'. Ironically, Naddaf has argued that Plato invented natural theology through the demonstrations he gives of God's existence, but says nothing about the importance of Platonic idealism for later natural theologians.
[133] The curtailing of anthropomorphism did not always help Christianity: Lightman has shown that agnosticism emerged from Mansel's denial of anthropomorphism in limiting the human mind's ability to know God (*Origins*).
[134] Whewell, *Astronomy* 360-361; Chalmers 1: 52-55; Babbage 23-34.
[135] Whewell, *Astronomy* 359-361; Chalmers 1: 21-25. By qualifying the similarity between human and divine creators, Whewell and Chalmers share Clarke's strategy for dealing with Leibniz's intellectualism (Alexander 22, 42).
[136] Engineers also occasionally recognized their limitations in contrast to God's power: 'In his presidential address to the Institution of Civil Engineers in 1839, James Walker departed from his prepared text to remind his colleagues how small and dependent were mankind's capacities in comparison to "the Mind which gave to them [i.e. the raw materials] the properties they have … and impressed upon matter those beautiful and uniform laws which govern it"' (MacLeod, *Heroes* 50, note 103).

Yet the distinction between human and divine inventors meant to curtail anthropomorphism ironically expanded the design analogy's explanatory power. Seeking to incorporate laws into natural theology, natural theologians like Whewell, Roget, and Prout distinguished law from matter then argued that law itself was a contrivance needing a designer, implicitly analogizing the causal nexus of the natural world to a human-made artefact.[137] Whewell, for example, rhetorically asks 'who constructed these three extraordinarily complex pieces of machinery, the earth with its productions, the atmosphere, and the ether? Who fitted them into each other in many parts, and thus made it possible for them to work together?' (*Astronomy* 141). Although drawing more on contrivance than law, Buckland declares that the 'self-same system of fixed and universal laws' must be sourced in 'the antecedent Will and Power of a Supreme Creator' (1: 578). Like machines as constructed by texts on mechanics, this machine of laws was passive. Law was drained of its autonomy: it had no inherent existence; it required the action of another power to jump start it; and, therefore, it was not enough to account for the universe. These natural theologians thus maintained a fundamental difference between the divine and human minds in relationship to law: law is independent from the human mind yet it is inherently dependent on the creating and sustaining work of the divine mind.

Although all of the Bridgewater authors incorporate the laws—or at least the regularity—of nature, only a few directly address the metaphysical question of how God acts or operates in a law-bound world. In doing so, they implicitly engaged the debate inherited from early modern theologians about how God relates to those laws of nature, negotiating both theological intellectualism and voluntarism in an early nineteenth-century context. The demonstrated homiletic and devotional emphasis on God's omnipresent activity employed in all the Bridgewater Treatises reeks of occasionalism, the doctrine that somehow God actively guarantees the link between cause and effect, compatible with both voluntarism and intellectualism.[138] Although seeming absurd to modern readers, Kirby carefully asserts

[137] On laws being made compatible with Providence in the nineteenth century through careful attention to the beneficial combination of laws, see Brooke, 'Natural Law' 88-89; and for various assimilations of active Providence and naturalistic explanation, see Topham, 'Teleology'.

[138] On the compatibility of occasionalism with both voluntarism and intellectualism, see P. Harrison, 'Voluntarism and Early'. On voluntarism as respectable in the 1820s and 30s, see Astore 59-69. On Chalmers as a theological voluntarist who interpreted the laws of nature as sustained by and expressing God's will but also allowing his intervention, see C. Smith, 'From' 62-63. On the obscured but foundational role of voluntarist and intellectualist theology to nineteenth-century science, even to Laplace and Darwin, see Osler, *Divine* 235-236. On the theological voluntarism and occasionalism inherent in early nineteenth-century energy physics, especially in the laws of conservation and entropy, developed by north British physicists like James Clerk Maxwell and William Thomson, see C. Smith, *Science*. On the idea in late nineteenth-century classical physics that entropy implies that the universe had a miraculous beginning, see Kraghe.

'inter-agents' between God and nature which maintain it, make it observe laws, link cause and effect, guarantee regularity, and impart motion and momentum.[139] For Kirby, God is 'maintaining by his own laws by his own universal action upon and by his cherubim of glory. WITHOUT HIM THEY CAN DO NOTHING' (1: ciii). Making laws depend on God's continued will, however, Kirby leans towards voluntarism, which emphasizes God's will and power rather than his knowledge.

The conjunction of mind and law creates the expectation that the Bridgewater Treatises will contain an intellectualist theology, which emphasizes God's intellect while precluding him from continued action. But the reality proved otherwise. Building on the anthropomorphic conception of law as an artefact, Prout and Whewell both voluntaristically insist that the laws of nature are not necessary, but are the product of choice and could have been otherwise.[140] But they align laws with an occasionalist voluntarism differently. Prout presents laws as the self-imposed limits 'within which [God] operates with the most unceasing and undeviating regularity and certainty' (19, 15-19).[141] Indeed, laws are the tools, the 'subordinate agencies' (16), the 'means' (167) he uses to achieve his purposes as he 'takes cognizance and regulates the movements of every individual atom in it' (172). For Prout, God's limiting of himself serves to make his action obvious to human observers (223) and implies that an active God is necessary to a knowable one.

Whewell takes a different anthropomorphic approach altogether in arguing for an active God in a regular and uniform world. He milks the law metaphor for all it is worth, consistently presenting God as a 'legislator' and 'governor' instituting and enforcing those laws (*Astronomy* 2, 3, 16, 257). And, on the human pattern, God-the-legislator does not walk away, for 'law supposes an agent, and a power; for it is the mode according to which the agent proceeds, the order according to which the power acts' (361). Whewell interprets the law metaphor through a legal/political lens rather than a mechanical one, seemingly incorporating divine action without running into the God-as-tinkerer problem raised by Leibniz.[142] While in isolation God-as-legislator seems to sidestep the problem, contemporary

[139] 1: xxxix-xi. Only Blaisdell has taken Kirby seriously.
[140] For their voluntarism, see Prout 173-77; Whewell, *Astronomy* 221-223; for their emphasis on choice see Prout 169-170, 223, 359-360; Whewell, *Astronomy* 22-23, 144, 211-212, 216.
[141] See also Prout 82, 178. As with Kirby, many scholars scoff at the strange compound of chemistry, meteorology, and digestion in Prout's Bridgewater Treatise. Only Brooke has taken it seriously as one of the first experiments in chemico-theology, see 'Religious Apologetics' 225-226.
[142] Natural theology had a changing relationship to its legal and political contexts. During the seventeenth and eighteenth centuries, natural theology supported the political status quo, including liberal Anglicanism, commercial society, and the English Revolution (Jacob, 'Christianity', *Newtonians*), while the law metaphor in the concurrent Scientific Revolution had strong political resonances (Brooke, 'Natural Law' 85-87, 98-101). A

concerns with legislating circle back to similar problems of agency and intervention. In discussing factory reform and legislation, political economists and policymakers had to address the questions of whether working men had agency, if it was appropriate to legally interfere with their lives, and whether it was philosophically justifiable to intervene in a seemingly self-regulating economic system with its own laws.[143] Whewell blends the legal with the mechanical law metaphor in addressing 'the Physical Agency of the Deity' (356-65) for he identifies laws as 'the instruments with which he works' but also discusses God as 'the author and governor' of and through those laws (357). Either way, he insists on an occasionalist interpretation of these laws, echoing Prout but exceeding him: 'laws of nature are the laws which he, in his wisdom, prescribes to his own acts; his universal presence is the necessary condition of any course of events, his universal agency the only origin of any efficient force' (362). Yet he notes that this divine activity is through laws, not through 'insulated interpositions of divine power' (356).

While later commentators have divided natural theology into miraculous, voluntarist contrivance-based or intellectualist natural law-based, the blending of divine mind and action with law comes to a metaphysical solution which emphasizes God's action *through* law itself. The turn to law was not necessarily intellectualist, but could be voluntarist through an occasionalist insistence on God's active role in law.[144] Drawing on an industrial anthropomorphism which championed human agency through the mind's relationship to the laws of nature, the natural theology of the 1830s harmonized God's will and his intellect, presenting an active God without miracles.

Whether solving the problem of divine agency or complicating it, the human relationship to machines anthropomorphically structured theological understandings of God, the laws of nature, and agency—and ultimately underpinned the psychological viability of natural theology. While industrial dissent challenged the grounds of the design analogy by dissociating man-the-maker from his product, it also re-packaged received, traditional

major legal resonance for natural theology in the 1830s was with changing conceptions of evidence: although discussing epistemology instead of the divine agency problem, McGrath has connected the new natural theological methodologies of the 1830s with changing understandings of evidence and proof in the British legal system (108-142), while Brooke and Cantor have noticed that natural theology, especially from Paley and the Bridgewater authors, became collections of evidence presented to the reader to judge, as in a courtroom (181-182). However, as metaphors for God shifted from king to father in the later nineteenth century, natural theology faded, according to Brooke, 'Natural Theology of the Geologists' 55.

[143] For accounts of these debates, see Gallagher; Gray; Hilton. Chalmers proffered a negative answer to that final question, suggesting that the system of laws governing human society is a God-ordained one and therefore to contravene it with new laws would work against God's will and therefore create significant problems for any social or political system.

[144] On the compatibility of law and Providence in early nineteenth-century natural theology, see Brooke, 'Natural Law' 88-89; Gascoigne 232-241.

theological understandings of human action and agency that helped articulate God's relationship to the universe. This agency involved both internal (mental and rational) and external (freedom of action) elements. Texts on mechanics intervened in this debate, capitalizing on this conception of human agency by recovering humanity's control of its mechanical products through knowledge of the laws governing them. Humans could again act within a technological world. At the same time, God's agency in a law-bound world often conceptualized through mechanical metaphors was also in question. Explicitly and implicitly absorbing the laws of nature as the centre of scientific endeavour, the Bridgewater authors asserted that God continued to act even through the regular laws of nature, but usually without contravening them. While they offered some sophisticated philosophical solutions, they implicitly relied on the perception, shaped by texts on technology, that the manipulations of matter through the knowledge of laws was evidence of the creative and continued control mind had over machine. Their methodological naturalism was theologically completed by an even more secular discourse, the contemporary culture of technology, which guaranteed mind—and therefore an agent—behind matter. Thus the recapture of machines by mind ultimately stabilized the theological implications of the laws of nature, making them assimilable to natural theology.

The Ambiguous Machine

Babbage's complaint stands. The Bridgewater Treatises largely sidestepped the miracles question, the Humean conception of law and miracles, and the Clarke-Leibniz debate in terms of law. But they did deal with the larger question of divine action, assimilating an active deity with a law-bound world, depending on an anthropomorphic comparison with the human mind's control of matter through laws. Yet this was a fragile compound, threatening to degrade when the more direct question of miraculous divine action was raised in relationship to laws.[145] Responses by Babbage and Powell in 1837 and 1838 triggered this deterioration by addressing very directly the question of miracles and the status of laws and divine action, respectively. For both, human interaction with matter was the basis for the metaphors they used to examine miracles and laws, building on the conjunction

[145] For various relationships of science and miracles in different debates in the nineteenth century, see Cannon; Mullin. In the 1820s, the question of supernatural action for apologetics rotated around prophecy (Corsi 23-24). Brooke has noticed a similar frailty when natural theology tried to incorporate—and neutralize—dangerous French science, see Brooke, 'Scientific Thought'.

of law and mind laid down by the Bridgewater Treatises and supported by constructions of human agency in the industrial world.

In his fractious and unauthorized *Ninth Bridgewater Treatise*, Babbage uses his own calculating engine as the foundation for a thought experiment on miracles. Imagine two engine-makers, one who is constantly tinkering in order to get things right and another who designed and assembled the engine so well it runs on its own. Which engine is better designed? The answer is clear: the one 'which had received at its first formation the impress of the will of its author, foreseeing the varied but yet necessary laws of its action, throughout the whole extent of its existence' (33). Babbage projects this conception onto the divine designer, suggesting that a 'perpetually interfering' Creator denies him both foresight and omnipotence (24-25), clearly echoing Leibniz's intellectualism and his use of a mechanical metaphor/analogy to exclude the possibility of miracles as law violations. But there is a twist: he uses a mechanical metaphor to defend rather than deny miracles, re-defining them in the process. He turns to his calculating engine for an example. It can be programmed to calculate a seemingly infinite series of numbers according to one equation but then on the *n*th term use a different equation, producing a result that seems miraculous to the observer because it did not follow the rules he had inductively observed (33-43). What appears miraculous is merely the working out of an unseen program, 'the exact fulfilment of much more extensive laws than those we suppose to exist' (93). Like Clarke, Babbage locates miracles in perception, not in physical reality.

Babbage gloats at his dispatching of the problem of miracles, but, ironically, with his mechanical metaphor the deistic conception that God could create, program, and then abandon the world returns with a vengeance as his intellectualist laws are allowed to function independently. His inability to maintain divine action with law-bound nature reflected his idiosyncratic view of the relationship between the human mind and the machine. His calculating engine was not just the product of mind, but was designed to replace the mind: it was an autonomous thinking machine that did not require the supervision of human rationality. His machine itself challenged the pro-industrial reconciliation of human agency with machines—and thus destabilized the assimilation of divine agency and law accomplished by his contemporary natural theologians.

Although not involved in technological innovation, Powell reiterates Babbage's opposition to an interfering, miracle-working God while also using human interaction with matter to articulate an intellectualist version of laws.[146] Criticizing those who see a law-bound world as somehow deficient, Powell quips: 'as well might we consider it to detract from the perfection of a piece of machinery, that it did not require the perpetual interposition of the artificer to keep it in action' (199).[147] While defending a non-interventionist God, Powell still theorizes God's action in the universe, if only at the moment of creation. Discussing causation, Powell outlines two types of causation, physical and moral (79-87). Physical causation is the regular chain of cause-and-effect observed in the natural world. Moral causation, on the other hand, involves 'voluntary agency'—'the action of mind on matter' (81). He illustrates the difference through the example of throwing a cricket ball: while the effect is physical as the ball moves through the air, the cause is in the mind of the thrower who intends and wills to throw the ball (81-82). Philosophically, for Powell, moral cause cannot be given to the physical, nor can all be reduced to physical cause (85-87). He then concludes that, as with man's action, there are material indications of a moral cause. A regular and traceable system of causes leads to awareness of 'an unseen intelligent agent' in the universe (115). Yet while he theorizes divine agency, he also only makes space for this mind-rooted action at the creation of the universe, denying any future intervention and siding with the intellectualists. In contrast to the Bridgewater authors, the invocations of human interactions with matter to discuss divine action led back to intellectualism for Babbage and Powell.

Taken together then, the industrial anthropomorphism of 1830s natural theology could both solve and deepen the problem of divine action, hinting at the ambivalence—the debated constructedness—of meanings of machines and their relationship to the human. As the works by Babbage and Powell demonstrate, the meanings of machines were not stable and reified, but shifting in both content and application. The industrial anthropomorphism on which the Bridgewater Treatises depended was only a brief solution, formulated at the convergence of the factory question and the growth of the science of mechanics in the early 1830s. But the concept of the autonomous machine was too powerful to the human imagination to be permanently counteracted by the convergence of pro-industrial apologists and mechanics textbooks for a few short years. As the decade advanced and moved into the 'hungry-forties', the perception of the machine's autonomy only grew in a time of perceived change, flux, and

[146] On Powell's denial of miracles as proof of revelation, but his acceptance of them because of revelation, see Corsi 148.

[147] While Powell clearly references Babbage, he also distances himself from Babbage. Instead of merely borrowing this conception from Babbage, he also constructs a historical tradition of this opinion, collecting intellectualist quotes contradicting an interfering God in his Notes (291-293).

rootlessness blamed on the Industrial Revolution. As people felt more and more out-of-control, the autonomous machine remained a powerful rhetoric. Nevertheless, in its own moment, in the mid-1830s, the Bridgewater Treatises offered a plausible, yet fragile solution to the problem of divine agency by drawing on the meanings of machines. And like machines, the laws of nature had ambiguous meanings which changed and shifted, an ambiguity which facilitated the anthropomorphic solution, but also led to its dissolution. With the changing conception of the 'laws of nature', according to Brooke, 'the association of natural theology with the extension of natural law had an effect rather like the Trojan horse. It smuggled a full-blown naturalism into territory that upholders of a more conservative natural theology, such as Whewell, still considered holy ground' (*Science* 223).

CHAPTER 5

Vestiges of the Natural History of Invention: Histories of Technology and Historicizing Design

God's action in the natural world was a multi-pronged problem for the natural theology of the 1830s. Mechanics textbooks had partly solved the abstract problem of assimilating God's agency with his character as all-wise Creator. But there was also the practical question of exactly how God acted which had been raised by recent and increasing interest in the history of the earth. How old was it? Did it change over time? How did God create the earth? What did his creative action look like? Where the emerging science of geology brought the conceptualization of divine creative action to the cultural fore, Hume had already problematized natural theology's anthropomorphic understanding of that act. According to Hume, the analogy with human design entailed a model of creation opposed to Genesis's. In his *Dialogues*, one of Hume's interlocutors suggests that from a ship we exalt the builder until we realize he is a 'stupid mechanic, who imitated others, and copied an art, which, through a long succession of ages, after multiplied trials, mistakes, corrections, deliberations, and controversies, had been gradually improving' (77). Human designs are produced by many people working haphazardly through trial-and error over centuries.[1] No one would want a God like these stupid, imitative, bungling mechanics, so Hume supposes.

Hume's ship objection makes the history of artefacts, including who invented them, when, and how, necessary to design's plausibility. But he wrongly assumes that his historiography was the only one available. In the 1820s and 30s, the history of British industrial supremacy, including its personal sources and great events, became of increasing interest to Britons, fed by a feast of 'histories of technology'. This genre joined a larger cultural debate about the nature of invention, which was often refracted through specific controversies about the assignment of priority, glory, and fame—about whether Watt got to be called the inventor of the steam engine, whether Arkwright had merely stolen the power loom from someone else, and whether the scientifically-elite Davy or the working-class Stephenson got the glory (and financial reward) for inventing the miner's safety lamp.[2] These debates over how to conceptualize human invention had ramifications far beyond

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[1] Hume gives another example: houses are built by multiple workers (*Dialogues* 77).
[2] Priority was also a major concern with electricity, see Morus, *Frankenstein's*.

explicit industrial culture: an analogy between how humans made things and how God made them was a major pillar in the plausibility structure of natural theology.

My previous three chapters have explored meanings of machines that made natural theology possible in the 1830s, thereby joining the scholarly conversation about its career in the nineteenth century. This project contradicts both the unexamined assumption that natural theology ended with the eighteenth century and the teleological attempt to understand early nineteenth-century natural theology through the cultural shift marked by Darwin's *Origin of Species*. Instead, it has added to existing scholarship, particularly by Brooke, which connects natural theology's resilience—and diversity—in this period to its usefulness, and by Topham, which considers natural theology's role as a genre of popular science.[3] Where Brooke focuses on its sociological utility and Topham on reading and publishing history, however, I have explored what made natural theology plausible as a religious discourse.

While natural theology's importance in the 1830s is now well-established, the question of its demise—whether placed at 1802, 1859, 1914, or still impending—and how to account for it still remains.[4] A number of theses have emerged: natural theology was destroyed by Darwinian naturalism; it self-destructed; it was 'eclipsed'; it persisted but with an ever-contracting cultural centrality; it declined when it was no longer useful; it deteriorated with the 'fragmentation of a common intellectual context' due to specialization; it lost its power as a 'larger apparatus of belief and practice'; its demonstrative function declined as its way of looking at nature was replaced by a Romantic aesthetic of nature; it crumbled as the alliance between science and religion deteriorated; it was excluded from increasingly professionalized science; it rose and fell according to denominational shifts; it disintegrated when its focus on 'personal subjectivity' divided theology and religion; and it caused its own demise by introducing concepts and evidences (particularly adaptation and natural law) that could so easily be re-interpreted from a naturalistic perspective.[5] Of this

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[3] See particularly Brooke, *Science* 192-225; Brooke, 'Why'; Topham, 'Science, Natural Theology, and the Practice'.

[4] Historians of mechanistic science choose 1802; Victorianists assume 1859; and Eddy suggests the problem of evil raised by the Great War ('Nineteenth' 114).

[5] For the assumption (often unexamined) of destruction by Darwinian naturalism, see Brock 162; Dupree 363; F. Gregory 385; Maas 164. On self-destruction, see Brooke, 'Indications', 'Natural Theology and the Plurality', 'Scientific' 55-56; M. Buckley; Ghiselin also suggests that it 'collapsed of its own weight' (278). On eclipse, see Gascoigne 25. On contraction, see Astore 13, 238-242; Lightman, *Victorian*, 'Visual'; J. Smith, *Charles* 77-91. On uselessness, see Brooke, 'Natural Theology of the Geologists' 51; F. Turner, 'Late' 94. On specialization, see Young, *Darwin's* 126-163. On its fading cultural power, see Jager 9. On the Romantic aesthetic in science, see Harman, *Culture* 22-52. On the division of science and religion, see Brooke, 'Scientific' 34-35. On professionalization, see Fyfe and Lightman, 'Science' 3. On denominational shifts, see Brooke, 'Natural Theology and the Plurality'. On personal subjectivity, see Gillespie, 'Preparing' 131. On vulnerability to reinterpretation, see Brooke, *Science* 223, 288, 'Scientific' 55-56; Gillespie, 'Divine' 215;

surfeit, no single theory can explain everything. Where Brooke and Topham have shown natural theology's diversity, Bowler has observed the 'complexity of the final stages of natural theology' ('Darwinism' 37). Brooke even blames its collapse on its diversification, in which different natural theological traditions could become 'mutually destructive', making natural theology a 'house divided against itself'.[6] The same variety, diversity, and complexity are also evident in natural theology's plausibility structure. That structure is multiple and each of its elements is variable and complex. Considered in previous chapters, many meanings of machines supported natural theology. But there were other meanings that had an at-best ambivalent and at-worst destructive relationship to natural theology in the nineteenth century, ones that weakened natural theology's plausibility. This chapter is about one of these slippages between natural theology and its industrial plausibility structure.

Histories of Technology: Historicizing Invention

In using the ship to attack design, Hume hit on a cunning—or perhaps very lucky—example. A century and a half later, historian S.C. Gilfillan famously used the ship as a case study of the gradual and collaborative nature of technological development, rejecting heroic narratives of the solitary inventor's light-bulb moment.[7] But Hume also errs: he assumes the ship stands for technology generally. Chronologically between Hume and later gradualist historians like Gilfillan, John Farey contrasted the ship's gradual development with the rapid development of the steam engine in 1827:

> The art of navigation, is the result of the combined ingenuity and experience of all nations, from the earliest period of history, to the present time; and the successive and almost imperceptible improvements, by which it has arrived at its present state of perfection, have, in most instances originated from accident, and been improved by continual practice: We do not know to whom we are indebted for the most important inventions, such as the mariner's compass, gunpowder, the telescope, &c., and many other most useful servants to human weakness and ingenuity have been first discovered by chance; *but the steam-engine is the invention of a few individuals, in the first origin it was*

Gillispie 105; McGrath 157; J. Robson 82. Brooke calls this the 'ironic pattern', in which evidences meant to demonstrate one thing slip into demonstrating the other ('Science and the Fortunes').

[6] Brooke, 'Natural Theology and the Plurality' 264, 272.

[7] See Gilfillan, *Sociology*, and its companion, Gilfillan, *Inventing*. For a theory of invention as systemic, incremental, and collective that is contemporaneous with Gilfillan's, see Epstein.

> *the result of philosophical inquiry, and the production of very ingenious minds* …. (3-4, my italics)

Where Hume assumed all human artefacts have a single kind of history, Farey recognized that different technologies have different kinds of stories. Narrating these histories came into fashion in the 1820s and 30s. Classifying histories, Thomas Carlyle claimed in 1830 that 'Goguets and Beckmanns have come forward with what might be the most bountiful contribution of all, a History of Inventions' ('History' 177). This genre established a historiography of technology different from Hume's and literally told technology's story, joining mechanics textbooks, factory reform literature, popular technologies, and industrial travel narratives in constructing cultural meanings of machines. It told a historical story, relating the who, what, when, why, where, and how of the invention of machines that produced Britain's international industrial supremacy.[8]

Although historical writing was nothing new, 'history' became a culturally-central narrative in the early nineteenth century, in what has been called 'the historical turn'.[9] It achieved this position because of the cultural work it could do. In a time of perceived rapid change, history offered a way of making sense of the present by understanding it through continuity with the past.[10] It often used the idea of 'progress' to make change 'part of a meaningful historical pattern' (Bowler, *Invention* 3). But where historians and consumers of history in the nineteenth century believed that history presented unmediated historical facts, later scholars have recognized that history as a genre is not ideologically neutral.[11] Participating in the 'linguistic turn' of twentieth-century theory, historians of historiography have used rhetoric and form as heuristics for tracking the ideologies of past histories.[12] Yet work on the 'Golden Age of History' in the nineteenth century usually focuses on work by the intellectual or literary greats—Carlyle, Macaulay, Arnold, Froude—and omits the popular, ephemeral, and unsophisticated, like histories of invention.[13] Informed by the awareness of history's rhetoric and in keeping with my conviction that the generic forms of

[8] For definitions of history-as-genre in terms of narrative, see Burrow 231.
[9] On the history of history as a genre, see Burrow. On the changing 'role history and historians have played' (xiii-xiv) in Western cultures, see Breisach. On the 'intimate connection between the new historical culture and the pervasive movement of Romanticism' (xi), see Bann, *Romanticism*. Corroboratively, Jann argues that the historical method was 'the preeminent paradigm' of the nineteenth century, while Bowler sees history as its 'preferred way of understanding' science and nature (*Invention* 1).
[10] See Breisach 228; Culler; Dellheim 31; Jann xv.
[11] On the nineteenth-century 'desire to repress the rhetorical status of historical writing', see Bann, *Clothing* 11-15.
[12] For a study motivated by a desire to reveal 'the rhetorical status of historical writing' (23), see Bann, *Clothing*; also Cook. This contrasts with intellectual histories of past historiography which focus entirely on the stated ideas of history, see J. Buckley; Parker.
[13] See, for example, Culler; Dale; Jann; Parker.

the literature of technology played an important role in producing the meanings of machines, this section will explore the generic and formal elements shared by early nineteenth-century histories of invention and then ask how those forms shaped the meanings of machines.[14]

Even before being applied to technology, historical writing had a complicated and mutually-influencing relationship with real technologies and perceived change in the nineteenth century. Increasingly aware of change and linking it directly to technology, early century thinkers turned to history to make sense of that change.[15] Recognized by most, the relationship between the historical turn and technology is understood differently: some suggest that the technological context drove people toward an opposing, non-technological past, while others argue that the turn to history was not in opposition to technology, but an incorporation of technology into history.[16] But even as history made sense of technology, so also technology was believed to change the way time was perceived.[17] Emphasis on change was itself a rhetorical construction within historiography, although an unconscious one. In this focus on change, early 'histories of invention' set the agenda for many twentieth- and twenty-first-century histories of technology which understand the history of technology as the history of technological change, even if they disagree about how to account for it.[18] This section seeks to understand how the relationship between change, history, and technology was constructed in the 1820s and 30s, pondering how technology changed time but focusing on how it was also made subject to time.

Their writers and readers would not have understood these texts as 'histories of technology', but in their own generic nomenclature as 'histories of invention', a richer and more ambiguous title. Despite consistent complaints about historiographical neglect, Carlyle's 'History of Inventions' was a recognizable genre by 1830.[19] The two authors he mentions could be seen as its inventors: the Frenchman Antoine-Yves Goguet and the German Johann Beckmann. Following on Goguet's *The Origin of Laws, Arts, and Sciences,*

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[14] On the historically variable meanings of history as a genre, see Burrow.
[15] This is widely recognized, see Bowler, *Invention*; Culler.
[16] For the technophobic turn to history, see Wiener; for the incorporation of technology into history, see Dellheim; MacLeod, *Heroes*.
[17] Pettit, '"Annihilation"'.
[18] Although outside of the purview of this project, contemporary approaches to technology's history could be usefully used as comparative foils to nineteenth-century histories of technology. For a now somewhat dated introduction to approaches and methodologies to technological change, see the essays collected in R. Fox. The hegemony of the concept of 'change' has been challenged only recently by David Edgerton's ground-breaking work on 'creole technologies', or technologies which have not changed and which will probably persist as they are.
[19] For such complaints, see Baines 7-8 (Preface), 53-54; Beckmann 1: 477; Guest 4; Henson 9; Johnston ix; Partington, *Historical* v; Radcliffe 5-6; Scrivenor 2; Stuart, *Descriptive* iv; Stuart, *Historical* 1: xxiii-xxiv; J. Williams 1: 3.

and their Progress among the Most Ancient Nations published in French in 1758, Professor Beckmann's four-volume *A History of Inventions and Discoveries* was published first in German from 1782 to 1805. Both texts were soon translated into English and various other European languages, going through a number of editions well into the nineteenth century and garnering their authors fame, if not fortune.[20] The translator's or editor's prefaces reflect the growing popularity of Beckmann's work in Britain, remarking that its importance 'is already too well established throughout Europe to render any comment on its merit necessary' (Preface iii) and that authors of dictionaries and encyclopaedias depended on it for reliable information.[21] These were not idle boasts. The importance of Beckmann's *History* was backed up by Carlyle's assumption that his readers would automatically recognize Beckmann and Goguet and by casual invocations of Beckmann as an authority across early nineteenth-century British periodicals from the *Quarterly Review* to the *Classical Journal* to the *European Magazine, and London Review*.[22] But while the *History*'s writing and publication were elements of the genre's invention, they would be historically irrelevant without the extreme favour with which the work was received. A book or two do not establish a genre; but when the book is republished again and again, when it is constantly invoked as an authority, and when its title is borrowed to name a set of texts, it becomes the prototype of a new genre. The reception of Beckmann's work has as much to do with the invention of the genre as does Beckmann's writing one of its first texts.[23]

In another way, Beckmann *did* invent the genre, not just by his authorship, but by his collection and naming of a tradition of writing about the history of technology. The third English edition included Beckmann's descriptive bibliography of works on the history of technology in French, German, Latin, Italian, and English (1: 475-518). He divided his bibliography into five, increasingly specific classes:

1) 'a general history of inventions, without any distinction'

[20] Goguet's *Origin* was translated into English with editions in 1761 and 1775. By the early nineteenth century, it had gone through fifteen editions and had been translated into several European languages (Wolloch). Beckmann's first three volumes were translated into English in 1797 by William Johnston, who later translated all four volumes for the second edition and third editions in 1814 and 1817. An abridged two volume version by an anonymous translator was published in 1823 and a fourth, compressed edition of Johnston's translation in 1846.

[21] Johnston xv-xvi; Preface iii. Achieving moderate fame, Beckmann even became an entry in the *London Encyclopaedia, or Universal Dictionary of Science, Art, Literature, and Practical Mechanics* ('Beckmann' 730).

[22] Beckmann's *History* was reviewed in the *Quarterly Review* 14.27 (January 1816): 405-429 and in the *European Magazine, or London Review* April 1823: 358. For references to Beckmann, see *The Classical Journal* 70 (June 1827): 170 and *The Monthly Magazine, or British Register* 9 (January-July 1800): 38, 40.

[23] As with twenty-first-century sociological histories of science and technology, my account of this genre's history links its development with social forces, interests, and needs, not just with who thought of it first.

2) ‘the inventions of individual nations, countries, or states’
3) ‘the inventions of a certain age or century’
4) ‘histories of inventions which belong to one science or art’
5) ‘one particular invention, or, only to a few’. (1: 475)

Not only did this taxonomy invent a genre of the history of inventions and technology from texts which came before it, but it also provides a framework for tracking the development of the genre in the texts which came after it in the early nineteenth century.

The popularity of Beckman’s general history induced imitations in the 1820s which solidified the *general collection* category of the genre. Parroting Beckmann’s title, Frederick Lake Williams published *An Historical Account of Inventions and Discoveries* in 1820 and Francis Sellon White published *A History of Inventions and Discoveries; Alphabetically Arranged* in 1827.[24] Although dismissing or neglecting Beckmann, they copy his basic format, reiterating his organization, timescale, geographical scope, and sources of evidence.[25] Like contemporaneous encyclopaedias and dictionaries, these works are collections of short, named entries each explaining a single invention’s history. Beckmann’s had no organizing paradigm at all, randomly including articles on such eclectic inventions as horseshoes, the paving of streets, butter, fire-engines, steel, lending-houses, leather snuff-boxes, plant impressions, coaches, and sowing-machines. Formatted similarly around short articles, the collections by Williams and White differ by having organizing principles: White’s is alphabetized while Williams’s is chronological, dividing human history into three epochs each with its own sequential inventions arising to meet human needs. While only Williams includes an overarching, structuring history, the entries in all three are in themselves mini-histories of single inventions or discoveries. Each article traces the historical origin and development of things, processes, and institutions in existence today. Although written at the tail of the Industrial Revolution, these histories locate most moments of invention or discovery in the remote past, some as far back as Biblical and classical civilizations. Giving the ancients credit for many of the important discoveries or inventions, they also depend on ancient textual sources augmented by texts written between 1500 and 1700. Some inventions they cannot place because they were so early in human history that there was no written

[24] By contrast, the entries in Cecil Hartley’s encyclopaedic collection *British Genius Exemplified in the Lives of Men; Who by their Industry or by Scientific Inventions and Discoveries Have Raised Themselves* (1820) were people who invented or discovered things or processes, again echoing Beckmann’s title.

[25] J. Williams’s only mention of Beckmann is in a footnote complaining of his *History*’s deficiency (1: 3), while White ignores him altogether.

record of them, as they say.[26] These are not archaeological histories, then, but textual ones.[27] Finally, connecting the history of civilization with the development of technology, these are geographically-broad, universal histories which ignore past and present national borders, including inventions from around the world.

At about the same time, texts began to appear which narrowed in on specifically mechanical technologies or industries, like Charles Frederick Partington's *An Historical and Descriptive Account of the Steam Engine* (1822) or Richard Guest's *A Compendious History of the Cotton Manufacture* (1823). These two fall into Beckmann's fourth and fifth categories: representatively, Guest's is a history of 'inventions which belong to one science or art' while Partington's is a history of 'one particular invention, or, only [of] a few' (Beckmann 1: 475). Beckmann's list progresses from the most general to the most specific, identifying different limits for each. In the case of histories of technology in the early nineteenth century, Beckmann's second and third categories, whose limits are the nation and historical period, are collapsed into the fourth and fifth categories: these texts generally focus on British technologies or industries and mostly discuss innovations from the previous one hundred years. Thus, modifying Beckmann's list, I identify three types of history of technology in early nineteenth-century Britain: *general collections* (Beckmann, White), *histories of a specific industry* (Guest), and *histories of a specific technology* (Partington) (Table 5.1).

While twentieth- and twenty-first century historians recognize that technology's history can be told in multiple ways, its nineteenth-century historians followed Beckmann's suit by focusing on *invention*.[28] But where 'invention' had been a catch-all frame for Beckmann, it became a focusing lens through which to view the histories of specific technologies and industries. Histories of the steam engine are organized around an incredibly consistent goal: to provide 'a descriptive history of the progress and improvement made in the steam engine' or to give a 'brief account of the invention of the steam engine, and the

[26] On the 'obscurity' of origins of many inventions, see Galloway 9, 10; Henson 20; Hodgson 1; Johnston ix-x; *Treatise on … Silk* 2, 211; J. Williams 1: 138; White iii.

[27] Beckmann carefully identifies his textual sources in each article while White's articles are culled from the work of other reputable writers (iv) which he includes in a timeline of his authors at the end of his text (541-547).

[28] For example, histories of technology can relate technology to past societies (Bijker, Hughes, and Pinch), can be about the use of a technology (Edgerton), can critique technology from a feminist perspective (Cowan; McGraw; Stanley), can focus on materials, or can interpret representations of or reactions to technology in the past (Marsden and Smith).

		Table 5.1: Histories of Technology, 1797-1842	
Date	**Author**	**Title**	**Type of History**
1797	Johann Beckmann	*A History of Inventions and Discoveries*	General Collection
1820	Thomas Hodgson	*An Essay on the Origin and Progress of Stereotype Printing*	Specific Technology
1820	J. Frederick Lake Williams	*An Historical Account of Inventions and Discoveries*	General Collection
1820	Cecil Hartley	*British Genius Exemplified in the Lives of Men; Who by their Industry or by Scientific Inventions and Discoveries Have Raised Themselves*	Biographical
1822	Charles Frederick Partington	*An Historical and Descriptive Account of the Steam Engine*	Specific Technology
1823	Richard Guest	*A Compendious History of the Cotton Manufacture; With a Disproval of the Claim of Sir Richard Arkwright to the Invention of its Ingenious Machinery*	Specific Industry
1824	Robert Stuart	*A Descriptive History of the Steam Engine*	Specific Technology
1825	James Cleland	*Historical Account of the Steam Engine and Its Application in Propelling Vessels*	Specific Technology
1826	Elijah Galloway	*History of the Steam Engine*	Specific Technology
1827	Francis Sellon White	*A History of Inventions and Discoveries; Alphabetically Arranged*	General Collection
1827	Thomas Tredgold	*The Steam Engine: Comprising an Account of its Invention and Progress*	Specific Technology
1827	John Farey	*A Treatise on the Steam Engine, Historical, Practical and Descriptive*	Specific Technology
1828	William Radcliffe	*Origin of the New System of Manufacture*	Biographical, Specific Industry
1828	John Ross	*A Treatise on Navigation by Steam: Comprising a History of the Steam Engine*	Specific Technology
1829	Robert Stuart	*Historical and Descriptive Anecdotes of Steam Engines, and of their Inventors*	Specific Technology
1830	Elijah Galloway and Luke Hebert	*History and Progress of the Steam Engine*	Specific Technology
1831	Gravenor Henson	*History of the Framework Knitters*	Biographical, Specific Industry
1831	[Anon.]	*Treatise on the Origin, Progressive Improvement, and Present State of the Silk Manufacture*	Specific Industry
1831-1834	John Holland	*Treatise on the Progressive Improvement and Present State of the Manufactures in Metal*	Specific Industry
1832	[Anon.]	*A Treatise on the Origin, Progressive Improvement, and Present State of the Manufacture of Porcelain and Glass*	Specific Industry

1833	Robert Bowie	*A Brief Narrative, Proving the Right of the Late William Symington . . . to be Considered the Inventor and Introducer of Steam Navigation*	Biographical
1834	Mary Strickland	*A Memoir of the Life, Writings, and Mechanical Inventions of Edmund Cartwright*	Biographical
1835	Edward Baines, Jr.	*History of the Cotton Manufacture of Great Britain*	Specific Industry
1836	Charles Frederick Partington	*A Popular and Descriptive Account of the Steam Engine*	Specific Technology
1836	Andrew Ure	*The Cotton Manufacture of Great Britain*	Specific Industry
1838	Hugo Reid	*The Steam-Engine: Being a Popular Description of the Construction and Action of that Engine; With a Sketch of its History, and of the Laws of Heat and Pneumatics*	Specific Technology
1839	François Arago	*Historical Eloge of James Watt*	Biographical
1840	Boyman Boyman	*Steam Navigation: Its Rise and Progress*	Specific Technology
1840	Hugo Reid	*Remarks on Certain Statements Regarding the Invention of the Steam Engine, in M. Arago's Historical Eloge of James Watt*	Biographical
1841	Harry Scrivenor	*A Comprehensive History of the Iron Trade*	Specific Industry
1842	James Bischoff	*A Comprehensive History of the Woollen and Worsted Manufactures*	Specific Industry

principle improvements which have been made on it from time to time'.[29] But this means multiple things. They all describe steam engines and carefully attribute their inventions to specific people, including the artefact and the acts of inventing it—and the inventors as real people. Thus 'invention' refers both to an event ('James Watt's invention of the steam engine') and a thing ('James Watt's invention, the steam engine'). They select inventions according to variable criteria often haphazardly combined: by whether the invention was used or practically applied, by when it was first built or when its principles were discovered or communicated, by its novelty or originality, or, perhaps most importantly, by when it was patented.[30] Thus their criteria of inclusion point to their understandings of what it is 'to

[29] Stuart, *Descriptive* 'Dedication'; Cleland 7. Here is a sampling of other purposes: to provide 'a complete account of the invention, from its first origin, to its present state of perfection' (Farey v); 'a faithful detail of what appeared to be the most interesting attempts to improve the steam engine' (Galloway 219); 'descriptive accounts of all the various Steam Engines that have been invented since the time of Hero the elder … down to the year 1827' (Galloway and Hebert iii); a 'sketch of its origin and progress' (H. Reid, *Steam* v); and 'a brief account of its grand epochs of improvement' (Ross 10).

[30] The criteria of 'use' could easily work against a history of the steam engine's 'invention', but they are easily married together in these histories. Galloway, Partington, H. Reid (*Remarks*), Stuart (*Historical*), and Tredgold take the use and practical application of the steam engine as their main criterion of invention. Stuart focuses on the first construction (*Descriptive*). However, while they may identify use or application as their primary criteria, the structure and content of their texts identify a different one: knowledge. On knowledge of principles

invent'. They also focus on different things: some on the inventors' lives, on the process of invention, on the technical details of an invention as a physical object, or on the principles of its functioning. Histories of specific industries have a similar purpose, to trace 'the history of the rise and progress of the iron trade to its present state' (Scrivenor 1) or the 'history of progressive improvements' in cotton machinery (Guest 4), but they add another layer by placing technological inventions and development in their commercial, legal, and political contexts. Thus their stories of technological innovation are just one part of a larger narrative. Their foci are also more diffuse as they seek to explain process, product, technology, use, and/or personal history. Yet explaining or ascertaining when a thing was invented and by whom remains central to their projects.

Despite their variety, these histories frame a technology's or industry's history through a consistent and ready-made narrative formula: they describe the *Origin, Progressive Improvement, and Present State of the Silk Manufacture* or try to explain the 'Rise, Progress, and Present State of the Machinery' for framework knitting (Henson). A culturally ubiquitous recipe, it is present in the goals these historians set for themselves and in the titles and sub-titles of their books, sections, and chapters.[31] Each term in the formula—rise, progress, and present state—illuminates the implications of this historiography. 'Progress' was central to pre- and early-Victorian understandings of themselves and of the past, and structures the way they construct meaningful histories of the steam engine or of industries.[32] Oozing with the ideology and vocabulary of progress, they describe the 'progressive improvements' of steam engines and industries. Borrowing the Enlightenment division of history into eras or epochs, they identify an 'Era of Invention' (Baines 113) in which technological change was concentrated.[33] Opposed both to the gradualism of Hume and

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versus construction of technologies in assessing 'invention' in the electrical industry in the 1830s and 40s, see Morus, *Frankenstein's*.

In general, attention to invention or adoption has dominated the historiography of technology: either who thought of it first, who applied it first, or how its use was diffused through a specific society. For a major exception, see Edgerton, who focuses exclusively on use.

[31] In the early nineteenth century, this formula titled histories of religious denominations, social institutions, trades and industries, sciences, laws, cities, social problems, and societies. A Google Books Search for "Origin Progress Present State" limited to publications between 1800 and 1850 produces this sampling of results: *Essay on the Origin, Progress, and Present State of Galvanism* (1816); *The Origin, Progress and Present State of the Thames Tunnel* (1827); and *The Nature, Origin, Progress, Present State, and Character of Wesleyan Methodism* (1840). In histories of invention, it was the formulaic title of several works in Lardner's Cabinet Cyclopaedia (example: *A Treatise on the Origin, Progressive Improvement, and Present State of the Silk Manufacture*) as well as of several sections in Ure's *Cotton Manufacture of Great Britain*, originally intended for Lardner's series (example: Book 1 is titled 'Origins and Progress of the Cotton Manufactures in its Handicraft State').

[32] On the centrality of 'progress' to Victorian ideologies, see Bowler, *Invention*; J. Buckley 34-52.

[33] On Enlightenment historiography as seeing history in stages and accounting for transitions between them, see Burrow 341-342. Bischoff identifies the 'great era of invention, and the application of science to manufacture' (1: 275); Galloway and Hebert see the invention of the steam engine as 'an era in the history of the world' (i);

Gilfillan and to the chronological depth of the general collections, they claim that most of the 'succession of improvements' (Guest 18) happened in a fairly short timespan between the early eighteenth century and its end. Within that narrow window, they divide improvement into 'progressive', 'successive', and 'chronological' 'steps', 'series', or 'stages'.[34]

Each text modifies this fill-in-the-blank formula of 'origin, progress, and present state' to fit the story it has to tell. Histories of the steam engine begin with a classical reference to first-century Hero of Alexandria before jumping a millennium and a half to the seventeenth-century Marquis of Worcester. But the story does not really begin until the 'Era of Invention' is started by Thomas Savery, developed through Thomas Newcomen with help from a few others, and completed by James Watt in the last third of the eighteenth century. These historians narrate serial, sequential inventions and improvements which increase the perfection of the steam engine, until Watt puts on its finishing touches. They describe inventions and improvements at the part level, attributing each to a specific inventor. In the terms of twenty-first-century historian Joel Mokyr, they tell the story of a macroinvention (i.e., the steam engine) by dividing it into microinventions (like the separate condenser).[35] The histories of industry, particularly of textile manufacturing, often bring together stories of multiple macroinventions. Assessing technologies in the context of industries, they begin by describing ancient methods of making or using things that remained static for thousands of years until the 'Era of Inventions' hit, whether with textiles, glass, or metals. Within this era, macroinventions are brought together both in the narrative and in factories to produce the industries of the texts' now. In the many histories of textile industries, the specific inventions begin with spinning by rollers in the 1730s and culminate in Arkwright's combination of the inventions of others into a near-perfect factory system, an innovation in itself.

While 'progress' turned change into 'a meaningful historical pattern' (Bowler, *Invention* 3), the 'progressive improvements' these texts narrate are not indefinite. The narratives layer another historical pattern over progress: perfection. Inherently teleological, they recount how technologies or industries reached a static point of perfection accomplished before the text's publication. Assuming an ideal to which technological development

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Guest celebrates the 'rapid progress of human discovery' in the 'present age' (3); Henson gives specific dates, labelling 1776-1777 as the 'era of experiments' on innovations in knitting and 1753-1780 as a period of 'rapid improvements' in the stocking frame (298-299, 257). They are only reiterating the self-understanding of the late eighteenth century as an 'inventive age', see MacLeod, *Inventing* 222.

[34] Again, a fairly unsystematic sampler: Arago 20; Baines 23, 211; Cleland 7; Farey 3, 306, 309, 645; Hodgson 55-56; *Treatise on . . . Silk* 2; H. Reid, *Remarks* 16-23, *Steam-Engine* 70; Ross 10; Stuart, *Historical* 1: 108.

[35] On macro and microinventions, see Mokyr, *Lever* 13.

continually advances, they frequently use ‘perfect’, both as a verb and an adjective.[36] Perfection language is present in most histories of industry, but is often unsubstantiated by the stories told, except with the textile industry. But although the industry as a whole may remain imperfect, the authors consistently refer to the perfection achieved in specific technologies, observing, for example, that the spinning jenny or stocking frame were just too simple and foundational—too perfect—to be improved.[37] Histories of the steam engine, however, are consistently teleological, recounting the perfection of the engine through both their language and structure. Structurally, they climax with Watt’s perfect engine, the typological terminus of technological progress.[38] Indeed, development before Watt is often expressed as a removal of ‘defects’, ‘inconveniences’, or ‘difficulties’, working toward his typological *telos*.[39] The detailed descriptions of engines consistently given by each author reflect their assumption of a teleological type. Advancing chronologically, they devote an increasing amount of text to describing the steam engine, some nearly abandoning the historical frame. These descriptions implicitly reify the engines into completed and stable forms rather than technologies in flux. Their illustrative diagrams stabilize these types, providing static models that appear complete and perfect, erasing any process of change (Fig. 2.2, 5.1).[40] In their teleological, technological idealism, these authors present a history in which this perfect archetype has been achieved in the recent past.

Their teleology was not just about the full expression of a technological archetype, but also about justifying their now. These texts are an egregious example of Whig history, defined famously by Herbert Butterfield as the tendency ‘to emphasise certain principles of

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[36] Although ubiquitous in nearly all of these works, ‘perfection’ is especially emphasized in Baines, *History*; Farey, *Treatise*. This teleology is backed up by the occasional metaphorizing of technology’s history to the process of human maturity, see Partington, *Popular* x; Stuart, *Descriptive* 10; Ure, *Cotton* 1: 169.

[37] Henson 332; Ure, *Cotton* 1: 198.

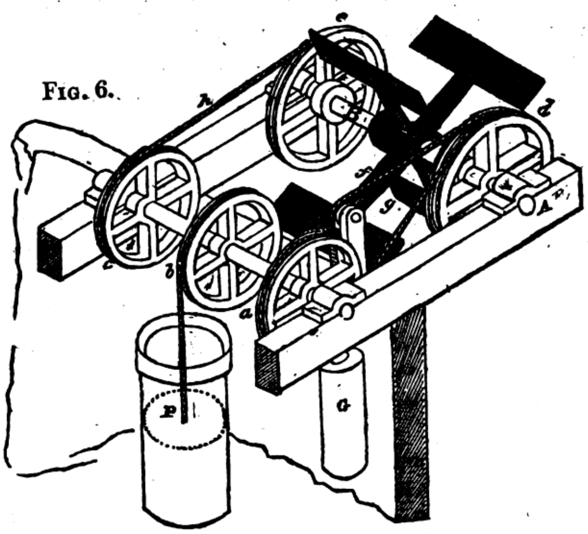
[38] Partington, H. Reid, and Ross stop dead at Watt. Those who include what happens after Watt faintly hope for more development, but are only confident about the development of new applications. Farey hopes to encourage innovation on the steam engine through his detailed work, but he also recognizes that ‘there have been no important inventions in practice’ since Watt’s time (viii); Galloway devotes two thirds of his work to describing the innovations in application but admits ‘little positive amendment’ in the engine after Watt (38); Galloway and Hebert focus specifically on its application to navigation; Stuart includes a few new applications but not new developments of the steam engine; Tredgold focuses on the development of the science of the steam engine after Watt.

[39] Stuart could suggest that failed inventions ‘contain all the rudiments required for a perfect machine, waiting only to be touched by the wand of some mechanical magician, to form a structure of surpassing ingenuity, and semi-omnipotent power’ (*Historical* 1: 101). See also Farey 133, 313; Galloway; H. Reid, *Steam* 112; Ross 17, 21; Stuart, *Descriptive* 67, *Historical* 1: 143.

[40] Galloway even tells his story backward starting with a drawing that ‘represents Watt’s engine with nearly all his improvements, and exhibits it in a state of perfection to which it was only brought at a late period of his life’ (32) and then returns to recount the history of each innovative part.

SECT. I.] THE STEAM ENGINE. 15

FIG. 6.



ward, and the ropes *g*, *h*, cause the wheels *e*, *d*, to move; the wheel *e* forward, and the wheel *d* backward, and the latter raises the weight G, which moves the wheel *d* forward during the ascent of the piston; consequently, the axis A B, with the paddle wheels, would be constantly moved round in the same direction, and by an equable force. This is certainly a beautiful contrivance for rendering so irregular a first mover equable, and considering the object it was intended for, it is not a complex arrangement; for besides equalizing the power, it gives a means of increasing or diminishing the velocity in the ratios of the diameters of the wheels. The pamphlet of Hulls bears evidence of being the work of an ingenious and well informed mind; and we must regret the causes which prevented his views meeting the encouragement they merited.*

1739. *Bernard Belidor, born* 1698, *died* 1761.

15.—Belidor, so eminently distinguished as a writer on the theory and practice both of civil and military engineering, treated of the steam engine in 1739, and undoubtedly presented the most accurate information then existing in France on the subject.† He gives a

* Hull's pamphlet may be seen at the British Museum, or the London Institution; and many civil engineers have succeeded in adding it to their own collections.

† Architecture Hydraulique, tom. ii. p. 300—331.

Fig. 5.1. Page image from Thomas Tredgold's *The Steam Engine: Comprising an Account of its Invention and Progress* (15), which lists inventions chronologically under an inventor's name.

progress in the past and to produce a story which is the ratification of the present' (v).[41] Teleologically, they select events or phases in the story according to whether they successfully produced the present, thereby studying 'the past with reference to the present' (11). But they are not even histories which attempt to understand the present moment in its totality, but are the 'less ambitious' histories, identified by Carlyle, which study the 'special separate provinces of human Action: … sciences, Practical Arts, Institutions and the like;

[41] They arrive before the prime example of Whig historiography, Macaulay's *History of England* (1848).

matters which do not imply an epitome of man's whole interest and form of life' ('History' 176).

They turn to the recent past to represent the present in a certain way. Unlike other nineteenth-century historians who used a distant past as a mirror for the present, these historians focus on a period that includes the current moment.[42] Unlike the general collections, histories of steam engines and industries usually begin around 1730 and end around 1820. Representing the present as heir of the 'Era of Invention', they respond to contemporary exigencies. Rhetorically, they explain national supremacy, argue for the benefits of machinery and the factory system, lobby for support for inventors and for patent reform, educate political leaders on the complexities of an industrial economy, soothe class struggle, and provide a frame for understanding technology in its technical detail. Written in a time of widespread agitation for reform accompanied by fear of revolution, they carefully insulate their stories from dangerous political events in history, like the French Revolution.[43] Recent technological change had not yet been labelled the 'Industrial Revolution'.[44] The texts downplay revolution by limiting technological change within a teleological structure, by emphasizing its slow speed within those limits, and by presenting their today's industrial and technological systems as perfect and complete, and therefore not in need of change.

Filtering the past through the present while using the past to understand the present, these histories make the 'Origins' of inventions just as important as their 'Progress, and Present State'. As with natural theology, attention to teleological ends in history went hand-in-hand with attention to beginnings. Histories of technologies and industries are fascinated by the origins of technology: first, with their origins in time and second, with who invented them and how to attribute invention. Locating macroinventions temporally was a fairly simple project, completed when these authors identify an 'Era of Inventions'. Framed by the present, they take an invention's status as an invention for granted, insulated from question by the evident historical outcome. But the question of who invented a technology, how, and when within the 'Era of Inventions' was more complicated. Answering the backward-facing question of which inventor should get the credit and why was an essential thread, often a

[42] On this mirroring according to a historian's own philosophical needs, see Culler.
[43] They hold a more complex relationship to reform: by writing machines into national history, they wrote industrial areas into the nation, implicitly supporting the redistribution of constituencies entailed by the Reform Bill.
[44] Although the idea, recognition, and occasional naming of an Industrial Revolution was present in France and Germany in the late eighteenth century, the idea was not common in England until the 1840s, although it had a nascent presence in some writing in the early century. Arnold Toynbee finally popularized the phrase 'Industrial Revolution' in a series of lectures given at Oxford in 1881-1882 and published in 1884. On the development of the phrase and concept, see Hudson 11; R. Williams, *Keywords* 166-167.

structural backbone, in these narratives. Many include accurate attribution of invention as a goal: Guest wants to determine who gets to be the 'original inventor' (14-15) while Baines plans to trace 'the origins of these inventions' and to assess the 'honour of inventing' them (53, 142). Complaining about how hard this project is, they recognize that there are many claimants to being the 'inventor' of something.[45] In early histories of the steam engine, Partington makes his simple attributions; Stuart disputes them (*Descriptive* 6), carefully weighs each inventor's claims, and attacks others' attributions (20-21, 31, 34, 55, 95-96), thus constructing a contested historiography of the steam engine; then Galloway begins directly with the controversy of who gets to be called the steam engine's inventor (9-12), repudiating both Partington and Stuart (v-vi).[46] Yet their disagreement rests on the shared assumption that inventions can and should be traced to individual inventors, a project made more difficult by an inherent imprecision and ambiguity in the term 'invention'.[47] To judge between competing claims, histories of inventions and industries develop a rudimentary, although often implicit, theory of invention, including definitions of invention, criteria for attribution, conceptions of the nature of the inventive act, and whether to allow multiple contributors.[48]

The nature of invention was not a culturally, socially, or politically neutral question.[49] In the 1820s and 30s, the inventor was constituted as either a hero or victim in service of a variety of social needs or cultural goals. As hero, he symbolized the outcome of middle-class values while also connecting British national supremacy to the arts of peace rather than of war. As victim, he was an example of unfair disenfranchisement used for discussing intellectual property.[50] Less prominent, the victim inventor myth was part of agitations for patent reform that began in the 1830s but did not blossom until 1852.[51] The culturally ubiquitous heroic-inventor myth was woven around James Watt, popularized by Francis Jeffrey's eulogistic 'Character of Watt' published in *The Scotsman* after Watt's death in 1819. The ideology was cemented by widely reported speeches at an 1824 meeting to discuss

[45] Baines 113-114, 119; Galloway 10; Guest 30; Henson 276; H. Reid, *Remarks* 15; Stuart, *Historical* 1: xli.
[46] Without engaging in historical debate, Farey carefully considers who gets to be called the inventor. Tredgold joins the fray, but with less contumely than Stuart. In histories of industry, Guest plans to correct the mistaken facts of others (29-30), while Baines and Ure in *Cotton* then dispute his attributions.
[47] Only J. Williams offers an explicit definition of invention: 'the projection and creation of something which has not yet had being' (1: 4).
[48] I borrow the concept of a 'rudimentary' theory of inventions from Joost, who searches out Whewell's 'rudimentary philosophy of technology' (338).
[49] On this question in relation to early electricity, see Morus, *Frankenstein's*.
[50] On the rhetorical importance of invention and inventors to nineteenth-century discussions of nation, class, and politics, see MacLeod, *Heroes*; Pettit, *Patent*.
[51] On mid-nineteenth-century patent reform, see Batzel; Machlup and Penrose. Only Pettit engages with the discourses on invention surrounding attempts to change patent law in the 1820s and 30s (*Patent* 1-83).

raising a monument to James Watt attended by political dignitaries, representatives of scientific culture, and prominent manufacturers.[52] Taken as both representative and exceptional, Watt symbolized inventors, displaying the psychology of invention to his adoring worshippers in the 1820s and 30s. Popularly, to know Watt's character and how he invented was to know what invention was and how it worked. He was a genius who alone perfected a rude engine in a fairly short space of time, spurring British commercial success. But while the speakers at the meeting agreed that Watt was a hero, they subtly disagreed about what made him an inventor and how invention worked.[53] Still, all lionized Watt, thereby inaugurating the major approach to the history of technology rejected by Gilfillan: tell technology's history by talking about a few compelling heroes.[54]

Although framed by this heroic ideology, histories of technology and industry in the 1820s and 30s relate to it in complex ways. Ubiquitous in public discourse on inventors, heroic ideology denies, or at least limits, a history of inventions. Watt comes along and—Presto!—the steam engine. There is little historical narrative or progressive development in that. Instead histories of the steam engine offer alternative narratives which continue to celebrate, but also to sideline Watt, assigning portions of glory to other contributors. By contrast, histories of industry proceed without a single overarching hero. Both sets of texts present inventors neither as heroes, as MacLeod would have it, nor victims, as Pettit would have it. Instead they put forward alternative, ambiguous, and ambivalent definitions of invention and inventors, undermining the widespread perception of the inventor as a solitary, heroic genius.

Necessarily rejecting mono-heroism, these histories do remain poly-heroistic: they need people to structure their historiographies. They solved the problem of how to connect the stages or steps of 'progress' by using people as bridges between them and sources for them.[55] Swirling together the histories of the artefact, accounts of the process of invention,

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[52] On this meeting and its rhetorics, see MacLeod, *Heroes* 91-124. Although not included in all histories of steam engines, Jeffrey's 'Character' and the monument speeches were appended to some of them. For the 'Character', see Cleland 35-37; Muirhead 175-182. For the monument meeting, see Cleland 12-35; Muirhead 183-239; Stuart, *Historical* 2: 562-582.

[53] On different interpretations of Watt, see MacLeod, *Heroes* 91-180. While Macleod reads the rhetoric of the heroic genius inventor in terms of class struggle (*Heroes* 145-152), Bizup reads the genius rhetoric deployed by pro-industrial defences of the factory system in terms of Romantic aestheticization of the origins of modern manufacturing (18-50).

[54] This approach was externally legitimated by its resonance with the Carlylean 'great man' historiography, given its strongest statement in Carlyle's *On Heroes, Hero-Worship, and the Heroic in History* (1841) and applied to the history of technology in Samuel Smiles's *Lives of the Engineers* in the 1850s and 60s.

[55] A few notice how inventors related to each other: Galloway claims that inventors knew and read each other, while, in the case of textile machinery, inventors (particularly Arkwright) stole the ideas of others through nefarious means (like getting a workman drunk) (Baines; Guest; Ure, *Cotton*), while H. Reid sees the inventors

and the biographies of inventors—they marry the biographies of inventors to the history of machines.[56] When introducing an invention, each text names an inventor, lists a date, and describes the invention's technical detail. Some link these elements visually (Fig. 5.1), but all do so verbally with active constructions: 'x invented y', rather than the passive 'y was invented'. Thus individual people, not physics or deterministic forces, get the credit for invention. Even when historians of industry attend to social, commercial, and political contexts shaping the development of an industry's technologies, they still give specific people the inventive credit. Not only does this specific naming of inventors conceal the arbitrariness of technological development, but it also maintained human agency in history. The biographical form was also itself already associated with genius through biographies of Isaac Newton, thereby crowning inventors geniuses by association.[57]

Each text proportions the biographical and the technical differently. Some spend a significant amount of time narrating an inventor's life and describing his inventive process, while others mention the inventor's names and circumstances only briefly before getting into the technical details. How much biographical detail to include was disputed. Galloway criticizes Stuart for too much biography and too little mechanical description (v-vi). Stuart defends his biographical focus and includes even more biographical information in his second work, even adding portraits of the important inventors (Fig. 5.2).[58] In some texts, the technical was utterly submerged in the biographical. A biographical and autobiographical genre, either celebrating industrial heroes or staking one's claim to fame or priority, began to develop at this time.[59] Using an inventor as a lens, they focus on snippets of a technology's history, weaving it into the man's life and often claiming a significant chunk of credit for him.

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of the steam engine as 'each working with the vantage ground of the hints of labours of those who preceded him' (*Remarks* 15).

[56] Biography played an important role in the construction of science in the early nineteenth century, see Hansen; Higgitt, 'Discriminating', *Recreating*. On the forms of biography, see Cantor, 'Scientific'. For current takes on the value of biography for the historiography of science, see Brooke and Cantor 247-281; Shortland and Yeo; Söderqvist.

[57] On Newtonian biography, see Higgitt, *Recreating*.

[58] *Historical* 1: xxxi.

[59] It did not blossom until Samuel Smiles's biographies in the 1850s and 60s

Integration of the personal into the technical and historical through accounts of the inventive process was modelled on Watt's own account of his contributions to the steam engine.[60] He details how he became interested in the steam engine and then narrates the experiments and thought processes that led to his specific innovations. Subsequent writers on technology's histories took up Watt's model. They describe the process through which an inventor, especially Watt, went as he came to his innovation.[61] For example, Farey, who gives the most detail, describes 'the history of the circumstances from which the great points of invention have originated' (vi). Writing a biography and its sense of a lived life over a

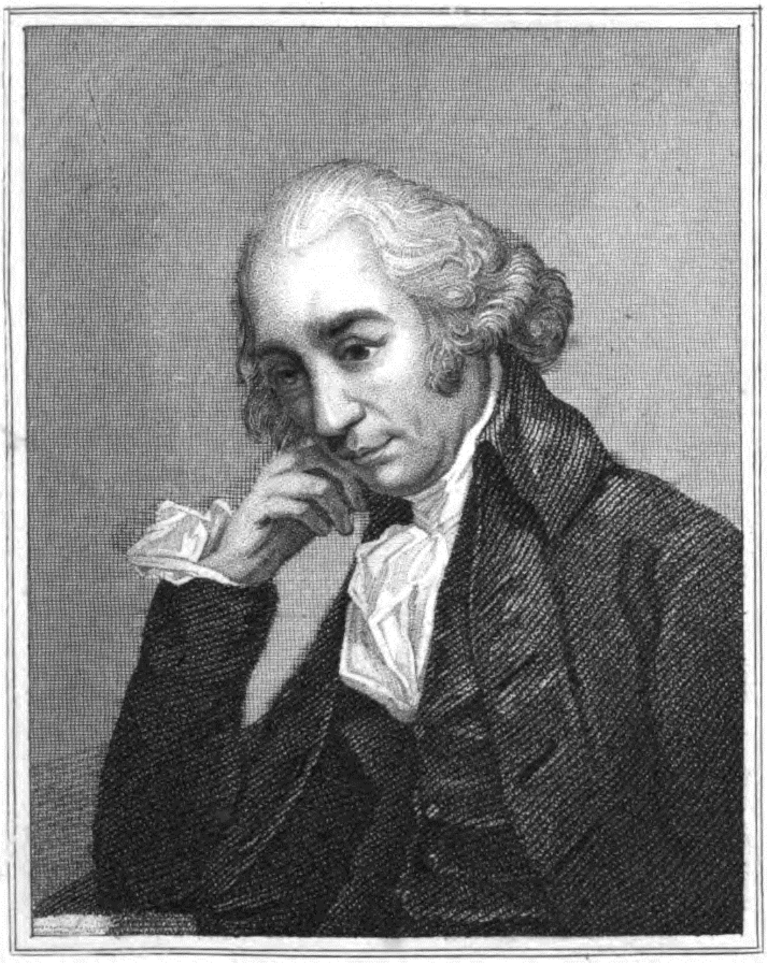

Fig. 5.2. 'Watt' from the frontispiece of Robert Stuart's *Historical and Descriptive Anecdotes of Steam Engines and their Inventors*.

[60] Appended to Brewster's 1822 collection of Robison's *Mechanical Philosophy* were James Watt's personal additions and corrections to Robison's 'On the Steam-Engine'. Watt stated that '"the account of this invention in the text not being perfectly correct, I subjoin the following short history of it"' (qtd. in Robison, *System* 2: 113).

[61] Although most do it, Henson and Farey offer particularly detailed descriptions of the process of invention. Stuart, *Descriptive*, ignores it.

span of time into a history of technology allows invention to take up time rather than being instantaneous. It stretches the process of invention over time, letting the reader see experiment, development, duration, and change within the limits of a single person's life. So while departing from the heroic model of invention spun around Watt, they do retain Watt's personal model but merge it with a sense of development in time rather than genius *ex machina*. Thus the biographical form and the narrative content of these texts suggest that invention happened in, through, or over time.

Doubting the heroic genius model of invention, these texts offer multiple and ambivalent models of invention as alternatives.[62] They use variable criteria, including use, application, adoption, construction, novelty, and knowledge to decide which things were inventions. While invention was a thing *and* something that happened, consideration of the thing was always rooted in consideration of invention as an activity, of what happened in the mind of the inventor: 'The principles of this valuable invention will be best explained by a statement of the manner in which it originated in the mind of the ingenious inventor' (Farey 309).[63] This balance shift, from thing to mind, is echoed in the frequently claimed emphasis on use, but actual emphasis on knowledge when assessing an invention. Yet invention-as-event was multiple in these texts: they give three major, overlapping models and a few minor ones. The minor ones include attribution of invention to accident, necessity, or specific personal circumstances like William Lee's disappointed love or Humphrey Potter's desire to go 'scogging'—to skip work and go play.[64] The three, not necessarily parallel, major models rooted invention in genius, science, or the working class.[65] Some describe the inventive process as the proverbial flash of genius, especially with Watt. In a Watt memorial speech, James Mackintosh claims that 'Wherever an original mind produces new combinations of thought and feeling, whether its means be words or colours, or marble or sound, or command over the mighty agents of nature; whether the result be an epic poem, or a statue, or a Steam Engine, we must equally reverence those transcendant faculties to which we give the name of

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[62] On the ambiguity of invention, see MacLeod, 'Concepts', although she modifies her position in *Heroes*, suggesting that the growing popularity of James Watt led to a fascination with the nature of invention (145-152). The concept of 'invention' continued to change into the twentieth century, see MacLeod and Tann.

[63] Farey discusses the 'Origin of Mr. Watt's Invention' at length (310-332).

[64] On accidents, see Beckmann 4: 311; Holland 1: 3-4; Stuart, *Historical* 1: 193. On needs, see Baines; Johnston 1: xi; Scrivenor 82; *Treatise on … Porcelain* 3; Ure, *Cotton* 1: 207. On Lee's personal circumstances, see Bischoff 2: 421; Henson 38; Ure, *Cotton* 2: 338-340; and on Potter's, see Arago 59; Galloway 22; Galloway and Hebert 25-26; H. Reid, *Steam* 108; Ross 18; Stuart, *Descriptive* 66, *Historical* 1: 160.

[65] Morus has traced the intertwining of these three models in claims to be an 'inventor' of electrical apparatuses in the 1830s and 40s (*Frankenstein's*).

genius' (qtd. in Muirhead 214). Farey provides the most sustained treatment of Watt as this type of heroic genius involving the 'spontaneous operation of the mind' (651).[66]

But while mentions of 'mechanical genius' and 'inventive genius' are frequent, they do not always denote a Romantic model.[67] Genius could be associated with being mechanically-minded or the guiding spirit of an industry, while it could also refer to the collective mindset of British workmen that produced the Industrial Revolution.[68] While Watt-as-genius was claimed by both the middle and working classes, he is most often seen as a 'mere mechanician' as he styled himself.[69] But genius also blended into science.[70] In his narrative of Watt's inventive activity, Stuart claims that 'When once the idea of separate condensation was started, all these improvements … were suggested in quick succession; so that, in the course of *one or two days,* the *invention was so far complete in his mind*, and he immediately began to submit them to the test of experiment' (*Descriptive* 105).[71] Stuart begins with the flash-of-genius model, then quickly shifts to an experimental one requiring long periods of time. The idea that invention was rooted in experiment and observation over time is not always reached through the deconstruction of genius, but also stands as the major alternative model to genius.[72] Indeed, Arago could say that the 'true secret of men of genius' was continual contemplation (7-8) augmented, in Watt's case, by 'indefatigable labour, by

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[66] See Farey 650-654. On Farey, see MacLeod, *Heroes* 145-152.

[67] Arago 69, 93; Hartley 3; Henson 40; Strickland 82. On the varieties of and shifts in the meaning of 'genius', see Fara, *Newton* 13-16, 164-166; Mason 107-134; Murray; R. Williams, *Keywords* 143-144. On specific invocations of the Romantic model, see Bizup 18-50. On its application to inventors, particularly Watt, see MacLeod, *Heroes* 145-152

[68] On mechanical-mindedness, see Henson 40. On the guiding spirit, see Ure, *Cotton* 1: 244. On the collective mechanical genius of British workmen, see Baines 242-244; Cleland 7; Galloway 16-17, 19; Henson 167; Stuart, *Historical* 1: xxxiii; *Treatise on . . . Silk* 90; Ure, *Cotton* 1: 1. The meaning of 'genius' was contested, with middle-class writers and working class radicals seeking to claim the products of that genius, especially Watt's, see MacLeod, *Heroes* 125-180. On scientists giving 'genius' a variety of meanings and linking it to an equally ambivalent 'industry', see Alborn.

[69] See Watt, qtd. in Robison, *System* 2: 113. For attribution of invention to mechanics, see Galloway 36; Galloway and Hebert 49; Partington, *Historical* 25; Stuart, *Historical* 1: 224. On the ideological importance of inventors beings mechanics, see MacLeod, *Heroes* 153-180; on the ideological importance of inventors being scientists, see D.P. Miller; for both, see Morus, *Frankenstein's*. However, whether Watt was a mechanic or a scientist, his being called a 'mechanic' lifted that term to a higher respectability: 'it was not long since the term Mechanic, even in this very country, enlightened as it now pretends to be, was used as a term of reproach … To Mr Watt, however, we are indebted for rescuing that name from opprobium, and for rendering it as honourable a title as any man could possess' ('Mechanics' Class' 319; qtd. in MacLeod, *Heroes* 113).

[70] On a scientific version of 'genius', see Fara, *Newton*.

[71] Watt's own account is qtd. in Robison, *System* 2: 117. This passage was quoted by Farey (314) and summarized by others (Galloway 21; Stuart, *Historical* 1: 234).

[72] On genius (exceptional inspiration or intuition) versus method (imitable and rational steps and rules) in the interpretation of Newton, see Yeo, 'Genius'; on the power of genius versus the power of rules and taste in the late eighteenth-century understanding of natural philosophy, see Schaffer, 'Genius'; on the division of scientific biography into Romantic (genius), heroic (discoverer), or utilitarian (self-improver), see Cantor, 'Scientific' 220.

experiments of excessive nicety and delicacy' rather than 'ingenious inspiration' (61).[73] Inherent in the biographical approach—and whether or not they use language of genius—these histories describe invention as a process of trial-and-error, continual observation, scientific reasoning, and experimentation tinctured by infrequent moments of inspiration.

The difficulty of separating genius from science from class in these models of invention was a systemic problem. Many authors held multiple models of invention simultaneously. For Farey, the steam engine was the product of genius, but other inventions were produced by 'imperceptible improvements' over time through the practice or accidents of unknown inventors (3-4). For Guest, the 'labour and meditation' of a single person produced the water frame (16), but the carding engine was 'not invented at once, nor by any particular individual, but was the result of a succession of improvements, made at various times and by different persons' (18). Tredgold presents different types of inventive processes with different people: Desaguliers wrote about ideas, Worcester came up with principles, Newcomen constructed the mechanism, and Beighton calculated and experimented. This ambivalence is endemic to these histories. But calling it ambivalence implies unresolved internal contradiction. Instead, I think this multiplicity is part of the point. They hold no single model of invention in time, but multiple models.

Not only is the act of invention drawn out over time and given multiple types, but it is also expanded synchronically like an accordion, attributed to multiple people, sometimes contemporaneously. Nearly all of these authors acknowledge the difficulty of deciding who the inventor of something is. Galloway complains that 'there is frequently great difficulty, even at this present day, in deciding who are the inventors of the most meritorious productions' (10) while Baines notices that history is 'sometimes obscure as to the claims of individuals' (113) and that the inventor of spinning by rollers 'has been the subject of much doubt and controversy' (119). But while they may want to name a single, heroic genius-inventor, they recognize that there are multiple inventors involved in the development of a major technology, whether the steam engine or textile factories. Bothered by disputes over the inventor of the steam engine, Arago suggests that the dispute's roots are in the false assumption that there is a single inventor. Instead the steam engine 'now embodies many ideas of leading importance, but entirely distinct from each other, which may not have proceeded from one common source' (21).

[73] On the importance of Watt's reputation as a philosophical (scientific) inventor, see D.P. Miller.

The multiplicity Arago recognizes is evident in the approach these writers take to assessing the 'merit' of each inventor. Instead of choosing a single hero, their goal is to list the multiple inventors and then decide which one is the most important or to portion out weighted amounts of glory to each.[74] Thus controversy about the steam engine's inventor is not just about Watt, but about who should get the most credit: Worcester, Papin, Newcomen, Savery, or Watt?[75] No one gets all the credit. This project is challenging: as Stuart observes, it has 'not been so easy a task to insulate the improvements of each artist, so as to prevent their merging into the more imposing labours of names of greater mechanical reputation, and at the same time preserve their proper proportion in the history of the progress of the machine' (*Historical* 1: xli). As told by these historians, the story of the steam engine is fairly simple. They disagree about rankings but include the same basic cast of characters. But histories of industries are more complex. Giving much more credit to collective development sourced in the 'inventive genius' of the working classes, they notice that 'nothing is more difficult than to decide with certainty, who is the real inventor of machinery, as, perhaps, there are several persons, at the same period, scheming and trying experiments, to accomplish a given end, each of whom have their partizans, who, as well as the projectors, lay claim to the invention' (Henson 276). Once again, then, the meanings of different histories as constructed by early nineteenth-century historians diverge. With the steam engine the focus is on distinguishing between inventors and improvers, implying development over time. With industries the focus is on distinguishing between contemporary, rival claimants to invention, implying multiple inventors working at one time. Thus linear and branching narratives emerge and contrastingly shape the meaning of technology.

Despite sharing out the credit, both sets of texts are pulled toward the hero vortex, retaining inventive figureheads even as they undermine the hero narrative. Watt dominates histories of the steam engine while Arkwright dominates histories of textile manufacturing. Both sets are still asking whether a single man—Watt or Arkwright—could originate world-changing invention, but the controversies about each were different. With Watt, the question is whether he was an inventor or an improver, while with Arkwright the questions are about priority, patents, and piracy.[76] Although Watt's class status and his relation to science were

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[74] On comparisons of merit and criteria for judgment, see Arago 38; Baines 140, 142; Galloway 14-15, 23; H. Reid, *Remarks* 12-15; Ure, *Cotton* 1: 230.

[75] Each had his partisans: Worcester had Cleland; Partington, *Historical*; J. Williams. Papin had Arago; Partington, *Historical*. Newcomen had Galloway. Savery had Stuart, *Historical*; Tredgold. Finally, Watt had the 1824 monument speeches; Ross.

[76] Each was also connected to different contemporary preoccupations: patent disputes resonated with questions of property, enfranchisement, and patent reform (Pettit, *Patent*) while Watt's reputation was connected with

the central points of dispute in the monument speeches in 1824, another implicit point of dispute emerged in the early 1820s: was Watt to be called the inventor or merely the improver of the steam engine?[77] Taking a cue from Watt's 1819 eulogist, Francis Jeffrey, some consciously upgraded Watt from improver to inventor, even as Brougham sought to temper that view by claiming that Watt saw himself as an improver.[78] Watt's reputation as hero-inventor of the steam engine depended on this upgrade. But many historians of the steam engine contradicted it, insisting that Watt was just an improver, albeit the most important one. By refusing the promotion, they resisted the impulse to single attribution. Galloway and Stuart even sneer that everyone who improved the steam engine in any way claimed to be its inventor.[79] Deciding on the 'merit' and 'rank' of each contributor to the steam engine, they all distinguish between inventors and improvers. Yet the distinction is often failed by their language: they frequently mix up invent and improve, insisting that someone is not an inventor, but using 'invent' and 'improve' to express his activities. Although verbally inconsistent, the concepts remain fairly stable, central to the goal of weighing the merit of each contributor to the steam engine.[80] Yet they are in a difficult spot: defining the steam engine as an invention—as a macroinvention that significantly changed life and culture—was necessary to attract readers. Breaking up its history into improvements risks downplaying its importance. So although they may call other men the inventors of the steam engine, they each give Watt pride of place with the most technical detail, the most illustrations, the most biographical information, and the most pages. Presenting Watt as an improver may have been more historically accurate, but it also demoted the cultural reputation of inventors generally. Nevertheless, the plots of these narratives support the improvement thesis: there are multiple contributors to the now-perfect steam engine. Indeed, the concept of improvement within invention meshed well with typological and teleological perfection. It highlighted that technologies develop and become perfect over time through the action of multiple inventors with different styles of invention. Returning to the difference

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class struggle and national identity (MacLeod, *Heroes*). Histories of industry, because focused on more than just machines, also had much larger claims to make about political economy and market regulation, especially on the vexed question of protectionism and the exportation of machinery, see Jeremy.

[77] On the significances of Watt's reputation, see MacLeod, *Heroes*; MacLeod and Tann; D.P. Miller; Torrens.

[78] Jeffrey 175. Brougham's comments are found in Muirhead 217-218.

[79] Galloway 9; Stuart, *History* 24-25.

[80] In distinguishing 'improve' from 'invent' to correct heroic invention stories, these texts formulate a rudimentary historiography of technology which is an early version of major twentieth-century historiographical concepts. In trying to understand the relationship between business cycles and technological change in 1939, Joseph Schumpeter differentiated invention from innovation, privileging the second as the significant factor in business cycles (1: 8-9, 84-102). At the end of the century, Mokyr's distinction between macroinvention and microinvention did a similar thing (*Lever* 13).

between Hume and Farey on technology's history, texts on the steam engine actually show that invention happened over time, but they link each improvement with a specific man, thereby taking up a place halfway between Hume and Farey.

By contrast, histories of textile manufacturing maintain a heroic conception of invention even as they quarrel about Arkwright's priority. Since the legal trials of Arkwright's patents, one of which had been overturned in 1785, his merits as an inventor had been hotly debated. Motivated by a desire to defend Lancashire's inventive merit, Richard Guest re-opened the debate in 1823 with *A Compendious History of the Cotton Manufacture* by attacking Arkwright's status as an inventor. Guest claims that Arkwright made 'no original invention' (20) and Baines follows suit, denying him 'the *creative faculty*' (195). Ure then defends Arkwright's claims, arguing against the evidence used to overthrow Arkwright's patent.[81] All three of these texts devote significant time to rehearsing and analysing the trials of Arkwright's patents, often including long excerpts of testimony in their appendices. Thus the question about Arkwright as an inventor was whether he invented something himself or merely pirated it from someone else. This is a less sophisticated model of invention which does not admit of degrees. Debating priority and plagiarism, they suggest that there can only be one inventor, but they also do allow that multiple people can be working on the same problem at the same time and that deception is possible. Still, only one can get the credit as only one person or party can get a patent for something.[82] Fortunately, there were multiple inventions, not just a single steam engine, to be attributed in the history of textile manufacturing, from spinning by rollers to weaving by steam power. Thus multiple people become inventors in these histories. Arkwright's merit, even to his detractors, was his collection and organization of these inventions into an efficient factory system.[83] The focus on patents and priority in disputing textile machinery ultimately supported a heroic model of singular invention producing macroinventions relatively perfect at their inception. Unexpectedly, the highly disputed history of textile manufacturing depended on a simpler model of invention, while the less disputed history of the steam engine assumed a more complex one.

Ironically, increasing cultural fascination with heroic inventors led to histories of invention which ultimately undermined that heroic model of invention. The narrative structures of these histories favoured a time-bound model in which technologies did not

[81] For an account of this debate, see Jeremy.
[82] See MacLeod, *Inventing* on the development of the patent system from the older monopoly practice, including the growing association of patents with novel invention.
[83] Baines 147; Guest 20; Ure, *Cotton* 1: 230.

develop linearly and simply, but over time and through multiple people contributing in different ways. There may have been an 'Era of Invention', but change within that era was not magical or *ex nihilo*, but produced by work, observation, and experiment. Yet they still remained confident that an 'inventor' could be named. This ambivalence shows up in a tension internal to their narrative structures. In seeking to describe the 'Origin, Progress, and Present State', the stories they tell about the 'origin' are often in tension with the story about the 'present State'. The story oriented around the present, the Whiggish teleological story, implicitly assumes that one historical event builds on another in a linear, continuous, and progressive series: 'Invention is progressive, every improvement that is made is the foundation of another' (Guest 48). Progress thus becomes the link which holds the phases of this history together. But history as a book genre, devoting thousands of words to the story, means that the sheer profusion of details—the number of inventors, technical descriptions, historical facts—mars the unity of the teleological narrative. When the details are put together in a book also seeking to discover the origin of an invention, the genre becomes an argument about priority and the nature of invention and tells a complicated, convoluted, and complex history of invention. Even when they name a single inventor, their historical narratives contain synchronic overlaps, diachronic competing plots, and historical gaps. A number of things work against linear, progressive narratives: stories intertwine, they cannot be told in a truly chronological fashion, failures contribute but not in a clear-cut way, inventions fade and then are rediscovered, and inventions can be made simultaneously.[84] The complexity in the origins of an invention was captured well by a metaphor Stuart developed for his updated history of the steam engine in 1829:

> A MACHINE, receiving at distant times and from many hands new combinations and improvements, and becoming at last a signal benefit to mankind, may be compared to a rivulet swelled in its course by tributary streams, until it rolls along a majestic river, enriching in its progress provinces and kingdoms.
>
> In retracing the current too from where it mingles with the ocean, the pretensions of even ample subsidiary streams are merged in over admiration of the master flood, glorying, as it were, in its expansion. But as we continue to ascend, those waters which, nearer the sea, would have been disregarded as

[84] Intertwining: Hodgson. Un-chronological narrative: Hodgson 114; Ross. Failures included: Cleland; Farey; Guest 8; Henson 277; Ross. Rediscoveries: Baines 119; Hodgson 17-38, 44-45; *Treatise on … Silk* 265. Simultaneous invention: Galloway and Hebert 25; Hodgson.

> unimportant, begin to rival in magnitude, and divide our attention with the parent stream; until at length, on our approaching the fountains of the river, it appears trickling from the rock, or oozing from among the flowers of the valley. So also, in developing the rise of a machine, a coarse instrument or a toy may be recognized as the germ of that production of mechanical genius, whose power and usefulness have stimulated our curiosity to mark its changes, and to trace its origin. (*Historical* 1: 3-4)

Trying to tame history, Stuart's river metaphor suggests that there is no single origin of an invention. These texts show that not only were there multiple inventors, but there were multiple types of inventive activity. While they want to retain the singular, heroic, patentee version of history and model of invention, what they actually do presents a totally different story. Looked at in theological terms, they present invention as an almost evolutionary process rather than creation *ex nihilo*. But this is not just metaphorical: their formulations of human invention and creativity reflected on the divine Inventor and Creator of the universe.

God the Inventor: Natural Theology and History

As Hume recognized, understandings of human invention formulated the foundational relationship on which the design analogy was built. Hume's attack on the analogy was not on whether an object implied a maker, but on what kind of maker the analogy reflected. How human invention and design were understood was as important to natural theology's plausibility as its evidence from nature; the design argument cannot work without an appropriate understanding of human making. Starting from this *a priori* assumption, it is unsurprising that natural theology experienced popularity when interest in human inventors was increasing. Histories of inventions and industries both registered and multiplied this fascination with *Homo faber*. But they also represented man-the-maker in ways which were not always beneficial to natural theology. Where my previous three chapters have argued for positive relationships between the literature of technology and natural theology, the rest of this chapter will do something different, looking at how histories of inventions and industries made natural theology more vulnerable and sometimes contradicted its orientation entirely. It will trace a fracturing and already-fractured relationship between them in two ways. First, the historicization of the inventive act accomplished in histories of technology ultimately destabilized the conception of creation upon which natural theology was built, making it more vulnerable to the contemporary naturalistic historicization of nature. This assumes that these two sets of texts still worked in the same direction, although beginning to take separate paths. Second, they had already splintered from each other by representing material things in totally different and bridge-burning ways.

Hume perceived that any historicization of invention would falsify the design argument, for who would want to understand God by analogy with the ship builders he describes? But although his rhetoric is powerful, Hume does not see that a different model of invention might have different theological resonances. Contrastingly, nineteenth-century histories of invention and industry are resolutely secular, mentioning God or Providence infrequently and the theological resonance of their models of invention not at all.[85] Yet those models had significant theological implications when filtered through the design analogy. Their two basic models—heroic genius versus inventive action over time based on trial-and-error—implicitly provided different conceptions of the divine creation of the universe.

The heroic genius model of human invention chimed with the conception of God as the Creator of the universe *ex nihilo*. The Romantic genius, eventually including inventors, created something new and original through a spontaneous, mental 'flash'.[86] This conception of invention/creation resonated with the Biblical literalist reading of the first chapter of Genesis in which God created a completely original universe out of nothing. Not only did the technological corroborate the theological models, but the conception of God as *ex nihilo* Creator implicitly structured the heroic genius conception of invention.[87] Relating the creation of man, Genesis 1.27 introduces the doctrine of *imago dei*: 'so God created man in his own image, in the image of God created he him; male and female created he them' (*KJV*).

[85] This secularity is a significant departure from eighteenth-century (and earlier) understandings of invention as Providential. In this model, the human inventor's mind was merely a conduit through which inventions, discoveries, and creations were delivered by Providence for the benefit of humanity. This conception began to shift in the late eighteenth century, with an increasing emphasis on the active powers of the human mind. For an intellectual history of the concept of creativity, see Mason. On specific elaborations or examples of this Providential model of invention in the eighteenth century, see MacLeod, *Heroes* 45-51; Stewart 42-59; Stiegler 125-128. References to 'Providence' in the 1830s histories are mostly likely to be to the port city in Rhode Island. The few references to divine Providence present it as a general, beneficial force gently driving progress (Bischoff 1: 231, 423, 2: 259; Holland 1: 1; Stuart, *Historical* 131; Scrivenor 14, 305; Ure, *Cotton* 1: xxiv, 169, 173, 224, 251; J. Williams 2: 40, 154, 267, 277, 301, 480).

[86] The characteristics of originality and spontaneity are evident in various early nineteenth-century definitions of 'genius'. In an 1815 addendum to the 'Preface' to *Lyrical Ballads*, Wordsworth suggests that 'of genius the only proof is, the act of doing well what is worthy to be done, and what was never done before …. Genius is the introduction of a new element into the intellectual universe' ('Essay' 82). Writing of Watt in 1827, Farey talks about 'genius, or the power of creating new ideas' (652), commenting also that 'the inventive faculty' involves 'a sort of spontaneous operation of the mind' (651), following Watt's own account of his invention of the separate condenser (qtd. in Robison 2: 117).

[87] Indeed, the association of genius with divinity was nothing new: in 1759 Edward Young asked what is genius 'but the Power of accomplishing great things without the means generally reputed necessary to that end? A *Genius* differs from a *good Understanding*, as a Magician from a good *Architect* … Hence Genius has ever been supposed to partake of something Divine' (qtd. in Fara, *Newton* 170).

The image of God presented in the preceding twenty-six verses is the Creator of the world—the God who spontaneously makes original stuff from nothing. Instantiating the early nineteenth-century consonance between theological conceptions of creation and anthropological conceptions of technological invention, John Bourne, a historian of the steam engine, could exclaim that 'Smeaton was able to *improve*, but Watt was able also to *create*' (21).

But while pro-design 'genius' functioned in popular discourse, histories of invention and industries presented an alternative, and seemingly anti-design, conception of invention as happening over time and through many people. In his *Eloge* of James Watt, Arago elaborated his multiple model of invention using a technology with specific natural theological resonances: a watch. Rejecting 'one sole inventor where it behoved to discriminate many', Arago suggested that

> The watchmaker best informed as to the history of his art, would remain silent before one who should ask, in general terms, who was the inventor of watches; whereas he would find little difficulty in answering the question, if it was put separately with reference to the main-spring, the various forms of escapement, and the balance-wheel. So is it with the steam-engine; it now embodies many ideas of leading importance, but entirely distinct from each other, which may not have proceeded from one common source …. (21)

Unconsciously, Arago turned Hume's nautical example into a horological one, with significant implications for natural theology. If God is patterned on the human inventor, then when Watt, the human figurehead for invention, is demoted, then God's creative activity is also demoted. While confidence in progressive development implicitly echoed Providentialist and teleological views of human history, the idea of a developmental history of invention with no single origin implicitly undermined the divine creative act of literalist Christianity. Although historians of technology did not yet have the language available to them, they presented an evolutionary history of technology.[88] Foreshadowing future evolutionary theories, they emphasized use and adoption (aligning with Spencer's 'survival of the fittest' elaborated in 1864), they highlighted the role of needs and of the environment (economic, political) in the development of technology, and they allowed huge gaps in

[88] This possibility has been elaborated by several twentieth- and twenty-first-century interpreters of technology's history, see Arthur; Basalla; Hughes; Mazlish; Mokyr, 'Evolution', *Lever* 273-304; Rennstitch; and the essays in Ziman. Stephen J. Gould has complained about this comparison between biological and technological evolution; while a philosopher of technology, Bernard Stiegler, has made the question of the similarity of the evolution of humans and technology central to his work.

technology's history, even if they tried to ignore them. And if the design analogy worked by collecting the meanings of technology and engineering and applying them to nature and the Creator, then it could accidentally net these historicized and nascently evolutionary meanings and apply them to nature and its creation.[89]

But the historicization of invention into trial-and-error, experiment, and thought over time could be assimilated to divine creative action if that action was understood as happening over time. Although evolutionary, these histories were still staunchly teleological so could support natural theology, even if pushing it toward a certain understanding of nature. Even if they resonated with evolutionary theories which would in future seem to defeat natural theology, that defeat was still a historically contingent one, not a necessary outcome. Whether histories of technology paved the way for a new understanding of the divine Creator who acted through and over time or whether they were destabilizing the plausibility structure of natural theology so that it was vulnerable to the evolutionary historicization of nature, these possibilities were two sides of the same coin.[90] The radical contingency of history and then the contingency of historiographical interpretation eventually determined which way the coin fell—and falls. Although, in hindsight, historicized invention seems to precipitate natural theology's defeat by evolution, these histories still maintained orientations which supported natural theology's plausibility: they were fully confident in the beneficial impact of inventions, they insisted on personal attribution of inventions, continued to highlight a few inventive heroes, focused on origins, and believed in originality.

So much for the deductive yet historically conjectural implications of early nineteenth-century models of invention. But how did natural theology deal with this historicization of human design in actuality? My above interpretations of invention implicitly assume that history was a problem for the design argument, but the relationship of natural theology to history is complex.[91] As an apologetic practice, natural theology's goal was to direct the mind to the origin of natural objects. From within an already Christian culture, that origin was easily conflated with the creation narrated in Genesis. Witnessing to the very first week of sacred history, natural theology participates in the inherent historical orientation of Christianity. But design's historicity stops there. While nature is subject to time, it does not change and thus has no history past those six days. The nature from which traditional natural

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[89] My argument assumes here that the divine designer and the human designer were similar. On the occasionally fraught theological considerations of that relationship in the eighteenth and nineteenth centuries, see Brooke, 'Detracting'.

[90] On other sources of that destabilization, see Brooke, 'Scientific'.

[91] On the tension between teleological and historical views of nature, see Brooke, 'Between'.

theologians like Ray, Derham, and Paley draw their evidence is the same world God gloried over on the seventh day of creation.[92] After creation, the natural world became either a prop or a backdrop for the human history in which God was more interested, becoming important only when God intervened in it to present a burning bush that was not consumed or to divide a major body to water to let miserable slaves pass through.[93] Then nature went back to normal. If histories of technology include the origin, progress, and present state of human-made designs, then natural theology ignores the middle term entirely, focusing on the power of the present state of nature to imply its origin (from *telos* to first cause). Indeed, our twenty-first-century conflation of natural theology with creationism makes us see it as more historical than it is. Assuming they constantly harp on about the creation as a historical event, we miss the fact that they focus almost exclusively on the natural world as it is now, allowing the reader to infer the origin.

In practice, the natural theologies of the 1830s took up many different positions with respect to time and to history. By-and-large the Bridgewater Treatises focus on describing contemporary nature and how it works. Yet they had varying attitudes about whether that nature had a past. At a time when the historicization of nature in the sciences, particularly geology, was in progress but by no means complete, some Bridgewater authors kept with natural theological tradition by assuming or claiming a temporally static and unchanging natural world.[94] Natural theology's most common history—natural history—was really no history at all, but an atemporal explication of the enduring order of nature.[95] The least temporally-aware Bridgewater authors even use the word 'history' exclusively in this sense, without any signification of time.[96] Whether or not they acknowledge chronology, natural history dominates the topics or structures of the treatises by Bell, Buckland, Kidd, Kirby, Prout, and Roget. For Kidd and Kirby, time has absolutely nothing to do with it. Organizing his treatise around the unchanging categories of animal, vegetable, mineral, and atmosphere,

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[92] On Paley's 'belief in the unchanging character of living forms', see Topham, 'Biology' 93-96; Gillispie 39-40. On the taxonomic natural theology of Derham and Ray, see Gillespie, 'Natural'.

[93] Nature-as-backdrop matches the natural world presented in neoclassical landscape paintings like those by Claude Lorrain and Nicolas Poussin.

[94] On history as the 'preferred way of understanding how … the material world operated' (1), see Bowler, *Invention*. On the historicization of nature through 'geohistory' in the late eighteenth and early nineteenth centuries, see Rudwick, *Bursting* for 1760-1820, and its sequel, *Worlds* for 1820-1845. Before Rudwick, Rappoport placed the historicization of nature through geology earlier in the eighteenth century. For a summary of geologist's ideas on time and history from the eighteenth and into the nineteenth centuries, see Oldroyd 131-144. For an older account of the historicization of nature, see Toulmin and Goodfield.

[95] On the importance of natural history for natural theology, see Bynum; Gascoigne; Gillespie, 'Divine' 218-219, 'Natural'; Gillispie 96-102. For reservations, see Astore; Gillespie, 'Preparing' 134-135.

[96] See Chalmers 1: 125, 199; Kidd 133, 151, 197, 217, 240, 251, 252; Kirby 1: 182, 183. The *OED Online* continues to include this definition as its seventh entry for 'history'.

Kidd claims that even the classificatory systems of natural history persisted basically unchanged between Aristotle and Cuvier.[97] Participating in an older tradition, Kidd, Kirby, and others, insist on a synchronic Great Chain of Being, with the least and most complex creatures existing simultaneously, created in the first six days of history.[98] Unconcerned with classification, Chalmers is nevertheless concerned with the descriptive natural history of humans, specifically with human psychology and sociology, assuming a stable and unchanging human nature.

An unchanging natural world, did not, however, necessarily entail a frozen one. Although many Bridgewater authors emphasized the regularity and constancy of nature, they also saw it as dynamic rather than entirely static.[99] Quoting John Robison, Chalmers identifies two types of science, one concerned with 'contemporaneous nature' or 'objects' and the other with 'successive nature' or 'events' (1: 25-26).[100] While Chalmers and the natural history writers focused on 'contemporaneous nature', many natural theologians incorporated time into their representations of nature in a number of different ways.[101] Direct philosophical statements about time are few, but the concept structures the thinking of the natural theological observers of nature, as Prout noticed.[102] Time ticks constantly on in the world of natural theology, evident in its interest in processes, causality, lifespans, periodicity, and the future. Many reference the 'operations', 'sequences', 'processes', and 'series' in nature, but Whewell and Prout highlight those processes, with a shared example in the dynamic equilibrium evident in meteorology.[103] This concept of process also fit within natural historical boundaries: digestion was a process with multiple phases, the animal body was constantly renewing itself, and the whole system of the animal economy was constantly changing as animals died but populations stayed within set numerical and geographical boundaries.[104] Whewell emphasized the stability of these temporal processes by beginning

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[97] Kidd 285-310. He even lines up similar quotes from Aristotle and Cuvier in his appendix (347-375).
[98] Kidd 145; Kirby *passim*; Roget 1: ix, 51-54. Beyond Arthur Lovejoy's hegemonic *The Great Chain of Being* (1936), see Yeo, 'Principle' for the impact on nineteenth-century natural theology of the 'principle of plenitude' embedded in the Great Chain of Being. This idea, that the least and most complex beings exist simultaneously, even shows up in the treatment of humanity and its arts in some of the Bridgewater Treatises: Kidd imagines a situation, no doubt based on accounts of imperialistic voyages, where savages in a canoe encounter a man-of war (77). On the risk, which was fulfilled by geology, that the Great Chain of Being could be historicized, see Rupke.
[99] See Chalmers 2: 136-146; Kidd 276-78; Powell 18-21; Roget 1: 7-8; Whewell, *Astronomy*.
[100] On the historiographical distinction between natural history and natural philosophy as the two forms of 'science' dominant before the historicization of nature, see Rudwick, *Bursting* 48-58.
[101] Chalmers thought 'contemporaneous nature' provided the best evidence of a Creator (1: 27).
[102] Prout 2.
[103] Whewell, *Astronomy* 106-110; Prout 178-412.
[104] On digestion, see Prout 480-551; Roget 2: 11-13, 105. On renewal, see Bell 10-12; Prout 541-542; Roget 2: 9. On changing populations, see Prout 164; Roget.

the evidential part of his treatise with periodicity, the temporally stable cycle of days and years, highlighting how the periodicity of plants and humans match the solar system's.[105] The same regularity in a process over time was present in insistence on the regularity of cause-and-effect, closely echoed in the more teleological means-and-ends relationship.[106] Even thought was acknowledged as a temporal sequence, although it could too easily get out-of-order and produce revolution or—worse—atheism.[107] Setting thought aside, these temporal processes are notably ahistorical: the same processes happen again and again without variation.

Two elements inherent to the Christian tradition began to erode this stability ever-so-slightly: an interest in the growth of individuals and a fascination with the future. Throughout his treatise, Roget hammers a piece of evidence which other authors gently tap: 'the progress of development in a single life' (1: 97) through 'successive stages of development' (1: 499).[108] As an animal body matures, 'prospective contrivances' in organs or structures form before they are needed, evincing design and incorporating a consideration of the future into natural theology. Others pick up this argument, but translate it into the spiritual realm.[109] They argue that the human conscience and desire for knowledge are currently unfulfilled contrivances that can only come to fruition through a future life—and therefore that there is an afterlife.[110] Incorporating the future in another way, Whewell values Laplace's nebular hypothesis because it implies that the universe had a beginning, which also implies an end. He then argues for a resisting medium that will eventually bring the solar system to its end (*Astronomy* 191-209).[111] Both approaches, to lifecycles and to personal or universal futures are teleological. *Telos* carried within it an ambiguity which introduced history into natural theology: it could refer both to utility now and to an ideal to be achieved in the future. This awareness of the future induced an awareness of the past: if the future was

[105] Whewell, *Astronomy* 17-41, 159-169.
[106] On cause-and-effect, see Powell 73-109; Roget 1: 5-6, 21-25.
[107] On thought as a temporal sequence, see Chalmers 1:32-35; Powell *passim*; Roget 2: 373; Whewell, *Astronomy* 304-308, 325-342.
[108] While Chalmers purposefully limits himself to a single person's development (1: 134), Roget generalizes about life, one of whose 'leading characteristics' is 'constant and progressive change' (2: 3) producing measurable epochs in an individual's life. See also Roget 1: 17-19, 302-309, 2: 599-618.
[109] Chalmers 1: 133-157; Roget 1: 44, 2: 155, 605, 617-618. On 'prospective contrivance' as a teleological argument, see Brooke, 'Between' 56-58.
[110] Chalmers 1: 151-154, 188-189, 2: 126-130; Prout 410-412; Roget 2: 640-641.
[111] Powell found Whewell's argument unconvincing (164-166). On Scottish evangelical assimilations of the concept of the decaying universe, see Baxter 107-109; on Whewell's approach to dealing with Laplace, see Brooke, 'Scientific' 44-48. The total amount of energy in the universe—and whether it was conserved or dissipated—was to have significant religious uses and implications for the British physicists of the second half of the century, see Gooday, 'Sunspots'.

different from the present, then the past could also be different from both, opening up the possibility that the natural world had a history.

Natural theology took up three understandings of time which seemed to deny a history to nature: nature was represented as atemporally static, as in constant and temporally-registered process, or as implying a future trailing concealed implications of a past. Although temporal, the nature they present was not historical. It was not contingent, directional, and unrepeatable, but stable and unchanging. Thus natural theology seems difficult to align with contemporaneous histories of invention. Where human inventions had multiple phases of development with multiple inventors, natural objects had only an isolated primal event followed by stasis. Natural theology was a still life where histories of invention were moving pictures. Yet the Bridgewater Treatises' representations of designed objects resonated with other ahistorical strategies of treating technological things: explication, taxonomy, it-narrative, and process narrative. When emphasizing static nature, natural theology is like the explications of steam engines in chapter two and the taxonomies of machines in chapter three. Using a natural historical frame, it describes the things of nature in detail then fits them into a fixed and unchanging natural order. When emphasizing the temporal and dynamic processes in nature, natural theology shares various characteristics with temporalizing process and it-narratives. Although not usually about technologies *per se*, it-narratives popular at the end of the eighteenth and into the beginning of the nineteenth centuries provided a particular temporal structure: the lifespan. 'A fictional autobiography in which a thing traces its travels among a series of richer or poorer owners' (L. Price 107), it-narratives begin with the creation and end with the demise of an individualized object. But while the specific object alters over its lifespan, the type to which it belongs remains unchanged.[112] While they eschew the it-narrative's autobiographical format, natural theologies like Roget's which highlight the animal lifecycle borrow the temporal parameters of the lifespan and the assumption of unchanging types. In contrast, the process narratives of a slightly later literature of technology, like Dodd's *Days at the Factories* discussed in chapter three, describe how products from buttons to dolls' eyes are made, presenting a reiterated and collective history.[113] But while there is constant making of objects, the production processes and the things they make stay the same, produced in an easily traceable way. Nature's processes parallel this industrial production: things are constantly being made, but they are made true to type as even the mode of production stays the same.

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[112] On the it-narrative as a genre, see the essays in Blackwell, *Secret*.
[113] On 'process narratives' in the 1850s, see I. Armstrong 18-36; Waters, *Commodity*, '"Fairy"'.

But where process narratives focused on how products are manufactured, natural theology remained surprisingly mute about *how* the world was made. While mentions of the creation as an event and act were increasing, their specificity was not.[114] Reticent about the creative act itself, the Bridgewater Treatises instead multiply specimens of design in nature *ad nauseam* and marshal them into a cumulative argument. In the words of Gillispie, they focus on the 'constitution of things rather than on their development' (39). As with a heroic-genius model of invention, there is no story to tell when creation is supernatural, immediate, and *ex nihilo*. A history requires a knowable process. Of the three presenting a static nature, Kidd says nothing about the creation, Kirby focuses more on God's relationship to on-going nature than its origin, while Chalmers is the only one who addresses the question head on. Concerned with how the design argument works, Chalmers compares the human inventor to the divine, continually asserting the divine's superiority (1: 13-27, 49-54). But his arguments are entirely *a priori*, based on the abstract idea that the substance of the natural world must have had an origin stylistically different from the origin of human-made objects.

Genesis would be the clearest resource for accounts of the divine creative process, but the Bridgewater authors treat it gingerly, partly because supernatural revelation is technically out-of-bounds for *natural* theology and partly because of contemporary controversy over 'Genesis and Geology'.[115] When they address Genesis, they do so in the context of dealing with scientific threats to religious belief, not with its account of divine creativity.[116] Only the traditionalist Kirby includes a chapter called the 'Creation of Animals' (1-43), narrating the events of the first few chapters of Genesis. But even he focuses on the products rather than processes of creation. Although omitting it as a historical record, the Bridgewater authors do draw on Genesis 1.27's theology of *imago dei* in emphasizing the intelligence of God-the-Creator. Most identify God's creative capacity with his intelligence. Only Roget dissents by consistently representing God as a skilled builder with 'the knowledge of the properties of matter, the selection and choice of particular means, and the power of employing them in an

[114] Compared to today's creationist and intelligent design theorists, these natural theologies say relatively little about the creation as an event or the Creator as its prime mover. But compared to their seventeenth- and eighteenth-century predecessors, they are relatively explicit about a supernatural origin and divine Creator (Gillispie 12-20). Gillespie suggests that the need to mention the creation implied doubt that all assume it ('Natural' 13), but I am not convinced by this argument because other cultural factors, like a fascination with inventors, could account for this shift within natural theology.

[115] On this conflict, see Gillispie. On this context as shaping the selection of the Bridgewater authors, see Brock 163. On the gap between the Genesis account of creation and the natural theological one, see Dupree 354.

[116] Kidd maintains that the authority of the Bible, particularly Genesis, should not be tied to science (189-183); Prout suggests that the Bible gives information about the general, but not specific, natural order (150-151); Bell and Buckland proclaim that the Bible is about humans, not about the universe (Bell 128-129; Buckland, 1: 27-28).

effective manner' (1: 22-23).[117] These two understandings of the Creator echo contemporary debates about whether inventors were intelligent scientists or dexterous mechanics. Carried into theology, a scientist-God would get it right the first time because of his superior knowledge while a mechanic-God would have to work by trial-and-error. This tension was dismissed by distinguishing between divine and human invention: God makes then arranges matter while humans only arrange it.[118] Humans come off as mechanics who arrange pre-existing matter, but God is the foreseeing scientist.

Inherent in this distinction between human and divine invention was also the impossibility of truly and totally grasping how the divine creative process actually worked. If not anthropomorphically identical with human invention, then it must be somewhat unknowable by human observers.[119] The most philosophically-engaged natural theologians recognized this: Whewell warns that humans cannot 'trace the order of thought in the mind of the Supreme Ordainer' (*Astronomy* 21) while Powell maintains that 'physical research cannot bring us to any distinct idea of the nature of creation' (150) and that geology cannot show 'the *mode* in which this has taken place, nor the process by which such a result of creative Omnipotence has been accomplished' (153).[120] In limiting the *imago dei* on which the design argument was essentially based, they sidestepped both Humean objections to the design analogy *and* the political and philosophical implications of different models of invention.[121] Their God was still a supreme genius inventor. Here again natural theology began to misalign with histories of invention.

Emphasis on God as the world's intelligent genius inventor can be understood as a response to the threat geology was perceived to pose to Christianity in the 1820s. Suggesting a historicized earth with many developmental phases that stretched back much further than 6,000 years, the new geology conflicted with the model of a divine, genius, creative intelligence who made the earth in six days.[122] In face of this challenge, the Bridgewater authors all address geology in one way or another—and often superfluously.[123] Most sought

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[117] For his construction metaphors, see Roget 1: 9, 33, 132-33, 139, 140-141, 344, 361, 377, 581; 2: 4, 617-18.
[118] Buckland 1: 35; Chalmers 1: 22-24, 49; Whewell, *Astronomy* 359-361.
[119] On the importance of conceivability, see Gillispie 42.
[120] Bell comments that the first giving of life was 'an act of creative power' that was 'inconceivably great' (41-42).
[121] On sidestepping Humean objections, see Brooke, 'Indications' 167.
[122] Rudwick has pointed out that geology itself was not the problem, for it could focus merely on cataloguing or mapping minerals, but that the subsection of 'geohistory' was the problem. On the emergence of geohistory, see Rudwick, *Bursting*, 'Shape', *Worlds*.
[123] See Gillispie's *Genesis and Geology* for an account of this threat in the 1820s and for its neutralization by the mid-1830s through discoveries of ways to maintain Providential guidance over the earth's history. For a slightly different account, see Moore, who argues that geology and Genesis were assimilated up to around 1830 through

to neutralize the threat of geology by integrating it, demonstrating that science was not at odds with religion. But some even used it to introduce new understandings of 'the creation' both as a thing (nature) and as an action (historical event). Geology became the vehicle through which Prout, Bell, and Buckland and then Babbage and Powell elaborated a historical understanding of nature and a historical model of divine creative activity.[124]

That all dealt with geohistory points to the huge cultural shifts which had happened since Paley's *Natural Theology* in 1802. Where Paley's opening image contrasted a watch with a knowable history to a stone without one, the Bridgewater Treatises acknowledge that the stone on which Paley's imaginary walker stubs his toe also carries traces of its past. In his highly-anticipated geological treatise, Buckland addresses Paley's image directly:

> 'In crossing a heath,' (says Paley,) 'suppose I pitched my foot against a stone, and were asked how the stone came to be there; I might possibly answer, that, for any thing I knew to the contrary, it had lain there for ever: nor would it perhaps be very easy to show the absurdity of this answer.'*
>
> Nay says the Geologist, for if the stone were a pebble, the adventures of this pebble may have been many and various, and fraught with records of physical events, that produced important changes upon the surface of our planet; and its rolled condition implies that it has undergone considerable locomotion by the action of water. (1: 572)[125]

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the Baconian conception of the two books (nature and revelation), but that this compromise began to splinter around 1830 with the emergence of Scriptural geology which interpreted nature through Genesis even as most amateurs and professional scientists continued to use nature to interpret Genesis ('Geologists'). For a third perspective, Corsi sees geology as a 'safe science' in the 1820s which became dangerous by the 1830s (50-55). While most histories of geology focus Whiggishly on those who were moving toward a secular geohistory, O'Connor argues that the scriptural geologists, like Granville Penn and our own Andrew Ure, deserve significant historical attention ('Young'). Instead of seeing religion and geology as exclusive, Klaver considers how religious sentiments and ideas inflected the geological ideas of Lyell and responses to them by Sedgwick, Buckland, Whewell, and some literary authors. Finally, Rupke looks at the special place questions of Christianity, especially of Genesis and of religious authority, had in the English School of Geology.

[124] The other Bridgewater authors addressed geology in the following ways. Kidd carefully defines geology as the description of the earth (173-187), while insisting that there is not—and could not be—any physical evidence of a miraculous Noachian flood (179-187). Chalmers is suspicious of geology's appeal to the laws of nature to explain change, but he also notices that it at least establishes 'a definite origin or commencement for the present animal and vegetable races' (1: 29, 27-30). Touching on geology vaguely and carefully, Roget notices that physiology's discovery of vestigial organs meshes with geological theories (1: 54-57). Calmly soothing fears, Whewell uses the vastness of past geological time inflected by the insistent need for an ultimate origin to help his readers understand the vastness of future time, but also the implication of the future end of the world, no matter how much time has elapsed (*Astronomy* 200-208). Even the blinkered Kirby addresses extinction, a historical possibility raised by geology (1: 16-20, 39-40).

[125] R. Young uses this same point to argue that with the attempt to integrate geology and geohistory into natural theology, 'it was no longer possible to do so on the model of a Newtonian Heavenly Clockmaker' (189). This, I believe, is a false reading of both Paley and of nineteenth-century natural theology. Presumably, Young believes that the universal horologue idea would mean that a static world was created by a genius inventor once and for all. Paley, however, offers a strange model of creation in which a machine could beget other machines,

He goes on to conjecture what the history would have been had the stone been sandstone or granite or had it contained a fossil (1: 573-574). Exactly like an it-narrative, Buckland narrates 'the adventures of this pebble', endowing the things of nature with histories both general and specific. In the geology integrated into natural theology, the earth itself became the thing with a history that would point to its maker and to his character.

Buckland's *Geology and Mineralogy considered with Reference to Natural Theology* was the only treatise to give a specific history of the earth as a thing, but Bell, Prout, and Babbage all agreed with Buckland on the basic structure of that history. Much older than six millennia, the earth had not always been in an unchanging, static state, but had undergone significant changes. There were two possible historical trajectories: either a type of punctuated equilibrium in which long periods of calm were occasionally disrupted by convulsions establishing new systems (catastrophism) or a gradual, but constant change (uniformitarianism). Buckland, Bell, Prout, and Babbage favoured catastrophism, while the ultra-liberal Powell lined up with Lyellian uniformitarianism.[126] Prout summarized their surprisingly consistent views: geology shows that 'our earth in its progress, has undergone, alternately periods of comparative quietude … and periods of derangement and convulsion, in which the preceding states of quietude and their consequences have been more or less subverted and a new order of things has been introduced' (179). Opening the scientific section of his treatise, Buckland maps these 'alternate periods' onto the earth's strata, detailing and structuring the earth's past through the primary, secondary, and tertiary series of rocks, each enclosing sub-eras.[127] True to geological methodology, this stratigraphy with its distinct layers differently coloured in Buckland's illustrations visually bolsters the sense of a past neatly partitioned into the eras of a classroom timeline (Fig. 3.7).[128] The strata point both to the epochal nature of that history and suggest what the convulsions were and what kind of system they established.[129]

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making for a dynamic yet mechanical world. Within the context of early nineteenth-century histories of technology, a new model of technological invention as happening over time, particularly in Arago's comments on watchmakers, allowed that the heavenly clockmaker could create over time.

[126] On his Lyellian view of geohistory, see Powell 42-47, 56-64, 67-70, 96-102, 148-154.

[127] Unlike his earlier work on the deluge, *Reliquiæ Diluvianæ, or, Observations on the Organic Remains attesting the Action of a Universal Deluge* (1823), Buckland focuses more on describing these strata than on the convulsive changes that happened between the epochs they mark. Quietly retracting his diluvial theories, Buckland quickly moves on to discussing the fossils embedded in these rocks.

[128] This dependence on the difference of the rocks and their colours was bolstered particularly by the geology and topography of Great Britain, allowing Hugh Miller to write a very popular work on the *Old Red Sandstone; or, New Walks in an Old Field* (1858).

[129] See Buckland 1:37; also Whewell, *Astronomy* 201.

But the 'adventures of this pebble' are not the primary interest of the geology-appropriators. Again, Prout presents the natural theological frame through which they viewed geology:

> it is the business of the Geologist to point out the changes which our earth has evidently undergone before it arrived at its present condition; to trace the earth as it were from a state of chaos through all its metamorphoses, whether sudden and convulsive, or slow and gradual; and to show that all these changes have not resulted from chance, but from the agency of an intelligent Being operating with some ulterior purpose, and according to certain laws. (179-180)[130]

Other Bridgewater authors elaborated the two threads present in Prout's quote: first, the earth's history as one of progress, and second, the providential guidance of that progress. Whewell, for example, presented the earth as undergoing 'perpetual change, perpetual progression' (*Astronomy* 203). The earth had not just perpetually changed in the past, but that change had been a directional, teleological development. This view participated in the growing ideology of progress which, according to Bowler, made change a 'meaningful historical pattern' and, within geology, provided a 'compromise' between 'old creationism' and the extremities of 'new materialism' (*Invention* 5).[131] With Providence at the helm of the developmental journey, the new geohistory was easily assimilated to Christianity, particularly into teleological natural theology.[132] Indeed, this continuous and directional view of progress was itself rooted in sacred history, in the idea that God directed human history toward and through certain events, some of which had already happened and others of which are in the future.[133]

So a progressively developing earth was not the real hang up with geology. Instead, it was how to understand the strange animals which inhabited those stages and where they came from. Under the pressure of new evidence provided by fossils, the Bridgewater authors rethought the divine creative act.[134] Righteously indignant over Lamarck's transmutation hypothesis and its side-lining of God from the work of creation, the Bridgewater authors

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[130] Whewell, Roget, and Chalmers also mention but do not elaborate the geohistorical model of creation.
[131] On the general confidence in the directionality of time and history in geology, see Rudwick, *Bursting* and *Worlds*.
[132] On invocations of Providence in geology, see Gillispie; Rudwick, 'Shape' 314.
[133] On the roots of the idea of progress in sacred history, see Bowler, *Invention* 9.
[134] In chapter four, I traced how important conceptualizing God's relationship to the laws of nature was for the Bridgewater authors. This concern with divine creative action is the back of this tapestry.

instead propounded the idea of 'successive creations'.[135] After a convulsion, God acted directly and miraculously to create the living beings fitted to the new, stable era.[136] In this theory of 'successive creations', God's supernatural creation was conceptualized as 'adapting' types to their environments.[137] In fact, Bell makes this adaptation of creatures to conditions the foundational assumption of his work, arguing that the geologist can infallibly reconstruct an animal's environment through the animal's physiological and anatomical details. There were two models of this adaptation of animals. Bell, and implicitly Roget, side with the slightly dangerous idea that the types stayed the same and were merely adapted in their details to their environments. Others progressively suggested that each creative act produced increasingly complex designs from lowest to highest over the geological epochs.[138] Devoting most of his treatise to discussing the structures of fossilized animals, Buckland uses the strata to draw attention to the different animals: 'the deeper we descend into the strata of the Earth, the higher do we ascend into the archaeological history of past ages of creation. We find successive stages marked by varying forms of animal and vegetable life, and these generally differ more and more widely from existing species, as we go further downwards into the receptacles of the wreck of more ancient creations' (1: 113). Prout and Bell, fusing geological progression with the Great Chain of Being, could even see humans as the perfect pinnacle of this development.[139] While the Bridgewater authors see the 'successive creations' as relatively isolated events at the beginning of each geological era, Powell suggested 'a continued, perhaps perpetual succession of creations' (153), in keeping with his Lyellian uniformitarianism. Rethinking the inherited model of creative activity in reaction to new scientific evidence, these natural theologians conceptualized divine creative action as

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[135] Prout, Roget, Buckland, Babbage, and Powell all discuss these events as 'successive creation'. Although they do not elaborate, Roget and Chalmers corroborate a similar understanding (Chalmers 1:30; Roget 1:54).

[136] Cannon has argued that this miraculous solution was actually more scientific than other solutions because it had more evidence and because it did not violate Occam's Razor. Babbage also applied his thought experiment with the calculating engine to this problem of the creation of species at the beginning of various geological epochs (*Passages* 389).

[137] On successive creations as 'adaptation', see Babbage, *Ninth* 44-45; Bell 2, 41-42, 180-181; Prout 158, 165-167.

[138] For example, Prout suggests that the earth 'by a succession of violent and disruptive changes, … has been progressively brought into different conditions, and progressively tenanted by higher orders of beings' (410-411) while Bell suggests that the 'progressive changes' from low to high in the history of animal structure suggests a beginning (264-265). Kirby, who allows geological change, denies any biological changes at all, believing that all animals were created in the beginning within a perfect taxonomic and ecological system (1: 56, 63, 189) while Kidd only allows some variation within species (326-334). On 1830s natural theology as assimilating 'progressive accounts of the history of creation' (89) in geology, astronomy, and progressive natural history, see Topham, 'Biology'.

[139] Bell 39, 44-45; Prout 410-411, 179-180.

multiple and as sometimes working with existing materials instead of always creating *ex nihilo*.[140]

Thus the geology-assimilating natural theologians historicized both nature and the act of creation. In nature, both the earth and the beings inhabiting it had gone through directional, teleological change, rather than remaining static as in the natural theology inherited from Paley, Derham, and Ray. The creation, as a divine act, had also gained a history in which the Deity acted multiple times to create increasingly complex products in at least two different ways: the originating creation *ex nihilo* and the adaptive 'successive creations'. Complicating the genius model of creation, the 'successive' model paralleled the model of human invention constructed by contemporary historians of technology. While traditional, ahistorical natural theology paralleled atemporal representations of technology, new natural theology's narrative of successive creations paralleled histories of invention in a numbers of ways: division of history into stages, confidence in that history's progress, belief in invention or creation as happening over time, and a celebration of humanity. [141] But the clearest parallel is in the historicization of the inventive or creative act. Like Watt with the steam engine, God took his time in creating the world. Produced by an urgent need to reaffirm God's creative action combined with confidence in scientific findings, the Bridgewater authors propounded a model of creative action that was supported by, if not based on, contemporaneous models of human invention. Establishing a direct connection between these two discourses is impossible, but the functioning of the design analogy coupled with the continuous importance of the methodologies of human history for understanding the history of nature solidifies their connection.[142]

My claim, that the historicization of invention made natural theology's 'successive creation' model possible, may seem, to some, unnecessary to account for changes in natural theology. Perhaps it merely yielded to the pressure of scientific theories. Indeed, why not stop at the usually referred to scientific context to understand natural theology? Simply, the new geology itself was not separate from culture. As Bowler has suggested, nineteenth-century Britons, 'created an image of the past which would fit with their ideology of

[140] Although suspicious of geology, Chalmers suggests that God both creates matter *ex nihilo* and arranges pre-existing matter while man only does the second (1: 49). Roget's consistent analogizing of divine creative activity to construction implicitly favours the understanding of God as manipulating existing materials. This is an excellent example of the 'traction' between science and religion which many contemporary thinkers on that topic see as necessary for the assimilation of those two entities, see McGrath 2-3.

[141] Twentieth-century historian of technology Joel Mokyr eventually would borrow the idea of punctuated equilibria propounded by evolutionary thinkers but exactly matching the model of earth history as convulsions followed by long periods of stasis to describe the history of technology, see *Lever* 273-304, esp. 291-292.

[142] On the structuring of geohistory by human history, see Rappaport; Rudwick, *Bursting*.

progress' across a host of disciplines, including geology (*Invention* vii). And this 'ideology of progress' was entangled both with technological development and with techniques the British used to understand and assimilate it in the early nineteenth century. Thus geology itself was structured by the progressive history of technology constructed by historians of invention. But the narrative of technology's development also offered special resources to natural theology. That narrative's model of invention guaranteed that specific inventors were traceable and their process of invention knowable, thus making the assimilation of historicized creation into natural theology possible.

Policing 'Successive Creations': The Plausibility and Vulnerability of Historicized Creation

Surprisingly progressive, this model of 'successive creations' in natural theology, made plausible by histories of invention, was both a good thing and a bad thing for natural theology. Positively, it maintained natural theology's traction with current scientific theories and advances. But negatively, it also presented natural theology's natural evidence in a vehicle that could easily be hijacked by naturalistic evolutionary theories.[143] Thus while histories of technology and their models of invention made a certain version of natural theology more plausible in the 1830s, they also made it more vulnerable the more it assimilated them.

Slippage between natural theology and the literatures of technology mitigated this vulnerability, but damaged design's plausibility in the process. While the historicized model of invention made divine creative action in geohistory plausible, natural theology did not swallow this model whole, but resisted assimilating some of its more dangerous elements. Although some natural theologians in the 1830s allowed multiple moments of divine creative activity, all denied multiple divine inventors and insisted that natural forms were created perfect, whether created at 'the beginning' or during 'successive creations'. Histories of invention put forward a different, more progressive theory about how types developed. With the steam engine, they begin with Hero of Alexandria's Aeliopile, something barely resembling Watt's double-acting engine which concludes the narrative. While assuming a broadly-defined perfect type in their Whiggish backward glances, these histories also narrate its development, telling a story in which no known ideal determined what any individual,

[143] J. Robson notes that 'adaptation' contained within itself 'a worm that aided in weakening Natural Theology' because while it was passive (something was adapted) in the Bridgewater Treatises, it was later interpreted as active ('something became adapted') (82). On vulnerability to reinterpretation, see also Brooke, *Science* 223, 288, 'Scientific' 55-56; Gillespie, 'Divine' 215; Gillispie 105; McGrath 157.

historical engine looked like. The type itself thus had a knowable, progressive history. The multiplicity of this typological history contrasts with the unity of type foundational to the natural theology open to nature's historicity. Buckland, Bell, and, implicitly, Roget, saw unity of design in nature across the various geological eras. Although each animal type might be adapted in its details to fit its specific environment, the essential type stayed the same.[144] So where histories of technology emphasized multiplicity and development of type, natural theologians emphasized unity and adaptation of type. Histories of the steam engine parallel Lamarckian transmutation theories, with each change rooted in the desire to accomplish a specific end and accomplished within a single life. In contrast, the Bridgewater authors may allow development through 'successive creations', but they flatly deny any transmutation, Lamarckian or otherwise.[145] This tension between histories of types, with the technological emphasizing multiplicity and the natural theological emphasizing unity, is one slippage between the design analogy and the plausibility structure built by literatures of technology.

Yet natural theology's eighteenth-century legacy worked against its own insistence on unity over multiplicity. Shaped by belief in the Great Chain of Being and its subordinate Principle of Plenitude, natural theology incorporated variety in nature and an understanding of nature's order which was vulnerable to developmental historicization. Inflected by plenitude, the Bridgewater Treatises celebrated the variety which existed within each strictly delimited species on the 'scale of being'.[146] Although a slightly outmoded concept, this scale continued to structure natural theology's understanding of the order of the animal and vegetable kingdoms.[147] Kirby, the most old-fashioned of the lot, directly used the concept of the 'scale of being' (1: 7), while others continued to see an 'economy of nature' in which all natural beings related to each other in a hierarchical way. The risk, of course, was that this hierarchy could be historicized, so that Lamarck's animalcules temporally preceded a slightly more complex creature and so on until nature's crowning achievement in man.[148] Indeed,

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[144] Buckland introduces the 'unity of design' (1: viii) early and then reiterates it continually in his discussion of fossilized animal forms. Bell claims early that 'we may see how the same system is adapted to an infinite variety of conditions' (2). Although mostly omitting geology, Roget proceeds by showing the similarity in the profusion of synchronic animal structures in various physiological categories, including the mechanical, vital, sensorial, and reproductive functions. Roget also clarifies that types 'have a real foundation in nature' and are not just in the human mind (1: 51).
[145] Bell 180-181; Buckland 1: vii; Kidd 309-311; Kirby 1: xxii-xlii; Prout 203-204; Roget 2: 638.
[146] Kidd calls it the 'law of deviation' (326-334), while Roget places '*the law of variety*' within laws of '*conformity to type*' (1: 48).
[147] The continuing power of plenitude is evident in Brewster's assumption of it in his defence of extra-terrestrial life in *More Worlds than One* (1854) written in response to Whewell's denial of extra-terrestrial life in *Of the Plurality of Worlds* (1853). On this debate, see Brooke, 'Natural Theology and the Plurality'; Yeo, 'Principle'.
[148] Rupke; Yeo, 'Principle'.

read out of context, even Kirby's anti-historical representation of nature sounds surprisingly developmental:

> As at the original creation of the animal kingdom, it was the will of the Supreme Being to begin at the foot of the scale and to terminate with man, who was its summit, thus making a gradual progress towards the most perfect being it was his will to create, and ending with him. (1: 145)[149]

Although Kirby's non-temporal 'progress' describes a synchronic hierarchy, his language aligns his story with the history of the steam engine, beginning with a simple machine and progressing toward that 'perfect being', Watt's double-acting steam engine. So the rupture between histories of technology and natural theology cannot be understood as a clean break, but as constantly fracturing and ossifying in new orientations, never as strong as the unbroken bone.

Where the Bridgewater authors were open to controlled deviation within the unity of nature's design, they mitigated historicized design's vulnerability through the unity of the divine creative force. All assume a single Creator, but Buckland constantly reiterates the 'Unity of the Intelligence and of the Power, which have presided over the entire construction of the material world' (1: 451). He elaborates on the structures of fossilized animals:

> From the similarity of these mechanisms to those still employed in animals of the existing creation, we see that all such contrivances and adaptations, however remotely separated by time or space, indicate a common origin in the will and design of one and the same Intelligence. (1: 316)[150]

Buckland's defence of monotheism in an age when atheism, not polytheism, was the prevailing enemy seems rather strange, but demonstration of this unity was a real theological problem at the time. In response to Irons's flat-out denial in 1836 that natural theology could establish the unity of the deity, Powell defends this divine unity against those who have 'urged that unity of plan might result from the co-operation of several minds, powers, or agencies' (*Connexion* 188-189, 187-189).[151] Rooted in noticing that the universe was a mixed bag of good and evil, Irons's denial resonated with Hume's ship objection: the ship did not have one inventor, but many over time. Historians of technology, especially of a single type like the steam engine, corroborated this point, listing the multiplicity of inventors involved in its development. While some natural theologians could allow multiple

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[149] See also Kirby 1: 4, 145, 190, 233-34, 273; 2: 213, 313.
[150] See also Buckland 1: 316, 380-381, 523, 582-583.
[151] Irons 128-149.

'successive creations', they could not allow multiple creators. Histories of technology could guarantee that a personal, individual inventor was behind each invention, but they could not guarantee that the same inventor invented them all, even if they emphasized Watt. Fracturing the parallel between inventors or creators in histories of technology and natural theology, this personal multiplicity damages natural theology's plausibility but also reduces its vulnerability to evolutionary reinterpretation.

Natural theologians themselves took up the project of limiting natural theology's interpretive vulnerability by carefully limiting the design analogy. Whewell and Chalmers differentiate between human and divine designers, noticing that humans only re-arrange pre-existing matter, while God both creates and arranges that matter.[152] Chalmers also notices that human designs are more respected when they are simplifications, but that divine design is more evident when complex, putting complexity and simplicity in tension.[153] Where Chalmers explores the distinctions between human and divine design to discover what the best form of the design argument is, Whewell asserts that theologians must 'go beyond the analogy of human contrivance' to access a fuller understanding of God.[154] While Chalmers and Whewell emphasize a category difference when distinguishing divine and human invention, Babbage and Roget remark only a difference of scale as God's designs are infinitely superior but similar to rudimentary ones by humans.[155]

But limiting the design analogy, particularly the relationship between human and divine creativity, could only go so far without making natural theology impossible. Such a powerful rhetorical tool as the design analogy needed itself to be scrupulously guarded. The Bridgewater authors simultaneously defended and policed the design analogy by trying to stabilize the meanings of human invention. But they did so reluctantly. Suiting the first cousin of the famous 'Canal Duke', the Earl of Bridgewater's bequest actually included the 'arts' in its prescription. The treatises were to illustrate '*the Power, Wisdom, and Goodness of God, as manifested in Creation*' through '*the variety and formation of God's creatures in the animal, vegetable and mineral kingdoms; … also by discoveries ancient and modern, in arts, sciences, and the whole extent of literature*'.[156] Yet the 'arts' very rarely appear in the

[152] Whewell, *Astronomy* 359-360; Chalmers 1: 13-31, 49.
[153] Chalmers 1: 49-52.
[154] Chalmers 1: 13-31; Whewell, *Astronomy* 360. In chapter four, I argued that this distinction between human and divine inventors in terms of matter and laws actually expanded the design analogy's explanatory power by distinguishing law as needing to be designed as well.
[155] Babbage, *Ninth* 33; Roget 1: 28-33, 344, 2: 459.
[156] This 'Notice' is included in the unpaginated sheets at the beginning of each treatise as published by William Pickering.

completed treatises. Even in *On the Adaptation of External Nature to the Moral and Intellectual Constitution of Man*, a title which implies treatment of the arts, Chalmers re-directs his treatise toward the relationship between an individual mind and society, apologizing that his subject departs from his assigned title.[157] In others, Whewell directly excludes 'use in the arts' from his argument about the beneficial adaptation of magnetism to navigation.[158] But, more deeply, Whewell was concerned with demarcating science from the arts, insisting that the arts were focused on utility and practical application while science was about pure knowledge for its own sake.[159] Distancing themselves from the low world of practical application and from the morally fraught world of the factories, the Bridgewater authors plus Babbage and Powell generally emphasize knowing over doing, science over the arts, God as an intelligent knower over God as a builder. Of the two sometime 'inventors' among the natural theologians, Babbage understands his work and his God as a scientific, intelligent knower, while only Roget takes the idiosyncratic position of consistently representing God as a builder, aligning his creative work with the tacit know-how of the untaught mechanic.[160] Despite Roget, this refusal to represent God as a builder constituted a strain which exacerbated natural theology's splintering from its technological plausibility structure.[161]

Even while trying to set practical knowledge at arm's length, natural theology in the 1830s still inherently trailed whiffs of utility, practice, and the arts. Ironically, its attempts to distance itself from the practical actually loop back to construct the meaning of technological knowledge and action, revealing a rudimentary philosophy of invention and human creativity. Although neither unanimous nor systematic, these authors had several explicit theses and implicit assumptions about the arts. Both inherited and culturally ubiquitous was an inherent, Baconian anthropocentrism that understood nature as made for man and understood man's

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[157] Chalmers 1: 1-10. Kidd's *On the Adaptation of External Nature to the Physical Condition of Man* considers how external nature is adapted to the mind of man, which makes nature meet his physical needs.
[158] Whewell, *Astronomy* 113.
[159] Whewell, *Philosophy* xli. On this distinction, see Yeo, *Defining*.
[160] Babbage famously invented the difference and calculating engines while Roget collaborated with Jeremy Bentham in developing a frigidarium and utilizing London's sewage, projects which earned him membership in the Institution of Civil Engineers (*ODNB*). In keeping with his representation of God, Babbage understood himself more as a thinking mathematician than as a contriving engineer, using his machine as a set piece, omitting any discussion of its development in his *Ninth Bridgewater Treatise*.
[161] Its resistance to the practical even puts natural theology in tension with its perceived system of distribution. Natural theology as popular science developed in a context where popular science was peddled to the working classes as *useful* knowledge available in Mechanics' Institutes, working man's libraries, and the publications of the Society for the Diffusion of Useful Knowledge. On natural theology as popular science, see Topham, 'Science and Popular'. On the usefulness of knowledge, see J. Harrison 57-89; Rauch. On the propagandistic advertising campaign promoting knowledge as useful which was designed to support middle-class control of the working classes, see Shapin and Barnes.

purpose as dominion over nature.[162] At the very least, natural theology assumes that one of nature's functions is to reveal God's existence to man. But more practically, Buckland, for example, wrote an entire chapter on 'Proofs of Design in the Dispositions of Strata of the Carboniferous Order' (1: 524-538), on the way geological faults and fractures give humans access to the 'inestimable treasures of mineral coal' (1: 525) otherwise hidden deep within the earth.[163] In parallel, many, like Kirby and Kidd, assume human dominion over nature, while others state it: Prout claims that iron and the fitness of the 'inherent properties of matter' to man's works enables man 'to place himself where it was evidently intended he should be, at the head of creation'.[164] This anthropocentrism implicitly supported the arts, suggesting that their development was part of human nature.

A tension thus arose within the natural theological view of nature: first, it presented nature as good and beneficial to humans, but, second, it assumed that nature needed to be tamed and dominated, a position corroborated by historians of technology. Natural theology solved this problem by presenting nature as suited to the exercise of man's faculties so that he could meet his own needs, completing the work of creation.[165] Making this point the most strongly, Kidd argues that humanity's purpose is the completion of creation, by using its God-given and God-like faculties to utilize the natural objects already adapted to its projects (144-152). Prout simplifies this stance, suggesting that 'whatever his wants require, he obtains by tools' (408). Technology thus completed creation and was therefore safe for natural theology. Although idiosyncratic, Bell could even claim that

> 'God made the country;' and it is perhaps in surveying plains and meads and mountains remote from man that the mind is most elevated to pure and high contemplations. But towns, temples, and the memorials of past ages, bridges, aqueducts, statues, pictures, and all the elegancies and comforts of the town, are equally the work of God, through the propensities of His creatures, and we must presume, for the fulfilment of design. (132)

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[162] On anthropocentrism, see Brooke, '"Wise"'. Lynn White has famously argued that Christianity's anthropocentrism led directly to the twentieth-century's ecological crisis ('Historical').

[163] See also Bell 132.

[164] Kirby 1: 3-4; Kidd 77; Prout 117. This was not a unanimous position: Whewell refused to consider usefulness to humanity as the only purpose of nature (*Astronomy* 113). Buckland softened this position, by seeing utility to humans as not the only purpose of nature, but one of them (1: 99).

[165] Others also presented nature as adapted to humanity's inventive faculties. In *The Quarterly Review* in 1849, Whitwell Elwin claimed that 'If we can sail in ships upon the great deep, it is because He supplied us with the wood for their constructions, and endowed it with buoyancy to float upon the waves. If we perform prodigies with steam, it is because He gave it an elastic power, ordained that fire should evolve it out of water, and provided us with both the water and the fire. We merely use the things with which he has presented us, and presented with a foresight of the end to which our capacities and wants would enable us to devote them. We can adapt, but we cannot create' (343).

Two things about the world enabled humans to be *Homo faber*: first, that the human mind was fitted to study nature while nature was adapted to that study, and second, that the mind had been paired with hands.[166] Some then appealed to the *imago dei* to certify this technological understanding of humanity and its purpose.[167] Brought under the umbrella of the *imago dei*, human inventions were similar to natural ones: boats were like bugs and pumps like hearts (Roget 1: 28-33).[168]

Some even join historians of technology by propounding models of inventive activity: Chalmers sees science and steam engines as the product of 'the fertility and power of the human understanding' (2: 158, 161); Kidd suggests that invention is the 'effect of divine inspiration' or 'the impulse of unassisted reason' in order to meet needs (279-283), but sides with the former; and Babbage presents knowledge as the product of intellectual work (57-58).[169] Human inventive activity could even be genetically related to God's inventive activity: humans could invent by contemplating God's work in nature.[170] In keeping with their representation of God as intelligent, they emphasize human intelligence and knowledge as the source of invention, just as many at the meeting for the Watt memorial claimed technological invention for science.

For those who admitted any kind of progressive development in nature, technological humanity was progress's *telos* and crowning achievement. A developmental anthropocentrist, Prout, for example, narrates 'the final step in the great design of the Omnipotent: the creation and the faculties of Man' (403).[171] As nature progresses to humanity, so also human civilization progresses, specifically in its technological dominion over nature. Chalmers celebrates 'every new triumph achieved by the human intellect over

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[166] On the fitness between mind and nature, see Bell 11-12; Chalmers 2: 157-158, 169; Kidd 339. On the relationship between hand and mind, see Bell 19, 248-253; Kidd 11, 18-19, 28-40, 76-77.
[167] Kirby 1: 4; Prout 402-403. This imitation is slightly different from the process theology present in some chemico-theology, see Brooke, 'Religious Apologetics'; Brooke and Cantor 314-346.
[168] Herschel affirms the same point (203).
[169] Although not directly about defining invention, many make comments about the concept's association: Kidd notes the 'similarity of principle' working in the human arts across the globe (279-283); Roget identifies technological accomplishment with difficulties overcome (1: 344) and asks readers to go about inventing the eye and then to compare their imagined invention to God's (2: 449-459); and Chalmers identifies technological accomplishment with simplification in elaborating the best design argument (1:49-51).

Natural theologians commenting on the course of human invention was nothing new. In the late seventeenth century, John Ray had seen invention of machines as part of God's provision for humanity which gave it both the mind and the material necessary to meet its own needs (161-165) while his younger contemporary William Derham understood humans as inventing by God's inspiration (*Physico* 270-271), making the proper use of 'Ingenuity and Invention' a moral standard (356).
[170] Kidd 157-159, 163-167, 279-283. On the natural theological frame through which sanitarians looked for inspiration on handling London's sewage in the 1840s-70s, see Hamlin.
[171] Bell connects that development directly with geohistory as man 'is in the centre of a magnificent system, which has been prepared for his reception by a succession of revolutions affecting the whole globe' producing 'the strictest relation … between the intellectual capacities and the material world' (39).

external nature, whether in the way of discovery or of art', including the steam engine, because 'in the indefinite progress of science and invention, the mastery of man over the elements which surround him is every year becoming more conspicuous—the pure result of adaptation, or of the way in which mind and matter have been conformed to each other' (2: 160).[172] Across the board, technological development is thus tied to the progressive development of scientific knowledge.[173] Allowing development that parallels histories of technology, Whewell can even comment that 'in looking back at the path by which science has advanced to its present position, we see the names of the great discoverers shine out like luminaries, few and scattered along the line: by far the largest portion of the space is occupied by those whose comparatively humble office it was to verify, to develope, to apply the general truths which the discoverers brought to light' (*Astronomy* 303-304). Where most natural theologians left their models of human invention unexamined and therefore assumed invention was historically static, Whewell recognizes that there are different types of inventors and invention, in-line with the historicized model of invention propounded in histories of technology. But while he acknowledges this diversity, his *modus operandi* is to focus on the 'great discoverers' (308-322) and their continued belief in God.

Where most of this thesis has followed the projection of meaning from human design onto divine, these last few paragraphs have begun to reverse that interpretation, looking at ways natural theology defined meanings of machines and asking how understandings of God the Creator could shape understandings of human creators. Most basically, the use of mechanical metaphors in natural theology implied that technology was good and beneficial. But it also had deeper reverberations, which this project unfortunately leaves mostly unsounded. Indeed, this whole project could have been reversed, investigating the ways in which conceptions of God the Creator structured conceptions of *Homo faber*. For example, the desire of historians of technology, against their own philosophy, to retain an understanding of invention as involving something completely new and life-changing was implicitly structured by the theological model of divine creation *ex nihilo*. Natural theologians themselves began this reversal, theorizing and stabilizing human invention in order to protect design's plausibility structure. But their attempt was ultimately too feeble to allay the fracturing relationship between the conception of invention available in histories of technology and the conception of creation required for natural theology. Indeed, this was an

[172] See also Bell 273-274.
[173] Babbage 30-31; Buckland 1: 6-8; Chalmers 2: 175, 195; Kidd 155, 159-160, 232-234, 273-286; Powell 33-35; Prout 1; Roget 1: viii, x; Whewell, *Astronomy* 70-73, 303-348.

impossible project. Whether they had the same or different conceptions of invention, natural theology was compromised for this specific historical moment. If the same historicized conception, then design was tied to an understanding of creation that would make natural theology particularly vulnerable to evolutionary reinterpretation. If different, then natural theology separated itself from its own plausibility structure, making the territory it had tried to defend unusable. Indeed, this paradox itself suggests that conceptions of human and divine design had begun to part ways, pointing to the weakening of design's plausibility.

Showing how natural theology and one element of its plausibility structure were splintering apart, however, does not prove the faltering of design's plausibility, the decline of its cultural importance, or the disintegration of its internal sophistication. Detailed study of the decades after 1840 would be required to make any such claim. Yet the functioning of natural theology's plausibility structure in the 1830s can help us understand natural theology's cultural career. Theories about natural theology's nineteenth-century career abound: that it declined when it was no longer useful; that it induced its own self-destruction through the rhetoric and concepts it assimilated; that it was defeated by naturalistic and evolutionary interpretations of nature and natural development; or that it continued but with a circumscribed cultural role. My study of natural theology's technological plausibility structure, however, suggests that there was no single unified culture which made natural theology possible, and therefore, that no single cultural strand can account for natural theology's career. In my externalist reading of natural theology, I have argued that three meanings of machines supported natural theology straightforwardly while another one compromised it. Where internalist accounts of natural theology say it self-destructs, I argue that the shifting, or fracturing, of one pillar of natural theology's plausibility structure made its evidence vulnerable to reinterpretation.

While supporting natural theology, histories of technology offered narratives of technological development that could become plausibility structures to naturalistic and evolutionary conceptions of nature. The major evolutionary statements of the nineteenth century, Robert Chambers's *Vestiges of the Natural History of Creation* (1844) and Charles Darwin's *On the Origin of Species* (1859), put forward two such conceptions of nature that borrowed but also renovated the narratives of technological development. In 1867, Karl Marx associated histories of technology with evolutionary theory:

> A critical history of technology would show how little any of the inventions of the eighteenth century are the work of a single individual. As yet such a book does not exist. Darwin has directed attention to the history of natural

> technology, i.e. the formation of the organs of plants and animals, which serve as the instruments of production for sustaining life. Does not the history of the productive organs of man in society, or organs that are the material basis of very particular organization of society, deserve equal attention? (K. Marx 493, n. 4)[174]

Yet Marx did not realize that such a 'critical history of technology' had already been accomplished by histories of invention, genetic precursors of evolutionary narratives. Like them, the stories told by Chambers and Darwin present development over, through, and across time. They amplify what is implicit in narratives of technological development: dead-ends, multiplicity, divergence, change. Chambers and Darwin even borrow specific discursive methods from these histories. Chambers's title itself refers to a 'Natural History of Creation', presenting a historicized model of creation. Chambers's recapitulation theory used the phases of individual ontogenesis to understand phylogenesis. The same language of maturity and growth that saturated the *Vestiges* had also shown up in many histories of invention.[175] The very title of Darwin's work echoes the titles and subtitles of earlier histories of technology with the parallel centrality of the word 'origin'. But the content of that contested word is also parallel. For Darwin, the 'origin' is not a single event, but a continual and continuing process, as Beer points out.[176] For historians of technology, inventions also have temporally elongated and personally multiple sources. Within the biography of an individual inventor, an invention is the product of time and tinkering, not genius or inspiration. Within a larger timeframe, a macroinvention develops over time, with multiple, branching, and overlapping lines of development in progress toward perfection. Darwin renovated this model by emphasizing the radical openness rather than teleological directionality of this change, a departure many of his readers missed.[177] Not only did histories of invention destabilize natural theology by complicating part of its plausibility structure, but these histories actually built a plausibility structure for opposing readings of nature. Yet the fact that natural theology and evolutionary theory depend on the same

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[174] Darwin himself wrote that 'When we no longer look at an organic being as a savage looks at a ship, as at something wholly beyond his comprehension; when we regard every production of nature as one which has had a history; when we contemplate every complex structure and instinct as the summing up of many contrivances, each useful to the possessor, nearly in the same way as when we look at any great mechanical invention as the summing up of the labour, the experience, the reason, and even the blunders of numerous workmen; when we thus view each organic being, how far more interesting, I speak from experience, will the study of natural history become!' (755).

[175] The ontogenetic lifecycle model, especially drawn from the process of maturation, was a common metaphor in histories of technology, see Partington, *Popular* x; Stuart, *Descriptive* 10; Ure, *Cotton* 1: 169.

[176] Beer, *Darwin's* 58-59.

[177] For teleological 'misreadings' of Darwin, see Beer, *Darwin's* 120-129.

plausibility structure accords well with readings of Darwin, for example, that emphasize the way his theories actually grew out of natural theology. Shifts in the meanings of machines, and thus in the external plausibility structure of natural theology, contributed to the emergence of evolutionary theory out of natural theological readings of nature.

But natural theology was not dead, even after Darwin.[178] Natural theology did not become extinct in a single cataclysmic event, but evolved over the century in a process of diversification. Where Chambers and Darwin built on the historicized view of the development of natural objects, they had abandoned the mechanical metaphors of natural theology and taken up their famous organic metaphors. They thus depended only briefly on the plausibility structure provided by this historicized meaning of machines. But while the historicization of invention made natural theological facts more vulnerable to evolutionary interpretation, it also opened new territory for a natural theology willing to stick closely to its elements. By implicitly insisting on the connection of inventions with personal inventors, the histories made an evolutionary natural theology plausible by presenting a model of human design and invention that could handle historical process and progress. Famously, the Reverend Charles Kingsley and George Campbell, Duke of Argyll, promulgated evolutionary theories of natural theology.[179] As Darwin excerpted a letter from Kingsley in the second edition of the *Origin*: 'a celebrated author and divine has written to me that "he has gradually learnt to see that it is just as noble a conception of the Deity to believe that He created a few original forms capable of self-development into other and needful forms, as to believe that He required a fresh act of creation to supply the voids caused by the action of His laws"' (Darwin 748).[180] In *The Reign of Law*, Argyll wrote with full confidence that:

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[178] On the continuance of natural theology well into the late nineteenth century, see Astore 238-242; Lightman, *Victorian*; 'Visual'.

[179] Theistic evolution and evolutionary natural theology in the final third of the nineteenth century have gotten a good chunk of attention: on natural theology as the 'intellectual framework' for absorbing Darwin's ideas into evangelical thinking, see Bebbington 131-135; on the idealism of the theistic evolution of Argyll, Mivart, and Carpenter, see Bowler, 'Darwinism' 37-41; on how theistic evolution was prepared for and then worked out in the decades leading up to Darwin's *Origin*, see Brooke, 'Between'; on Christian popularization of Darwinian theories in the second half of the nineteenth century, see Lightman, 'Darwin' 17-19; on different uses of the 'discourse of design' to respond to and assimilate Darwin into popular science, see Lightman, *Victorian* 39-44; on evangelical defenders of Darwin's ideas, see Livingstone; on Philip Henry Gosse's absorption of Darwin's ideas into his natural theology, see J. Smith, *Charles* 77-91; on providential evolution before and after Darwin's *Origin*, including in the early thinking of Darwin himself, see Gillespie, *Charles* 82-108; on continuing resistance to Darwinism within design-saturated natural history, see Johnson; and on the possibility, but not popularity of theistic evolution, see Topham, 'Teleology' 154-155.

[180] In a lecture read in the Hall of Scion College in 1871, Kingsley reiterated one of his most famous ideas: 'We knew of old that God was so wise that He could make all things: but behold, He is so much wiser than even that, that he can make all things make themselves' ('Natural' 377). The same concept appeared a decade earlier in *The Water-Babies*, in which Mother Carey tells Tom that 'I am not going to trouble myself to make things, my little dear. I sit here and make them make themselves' (201).

> It is no mere theory, but a fact as certain as any other fact of Science, that Creation has had a History. It has not been a single act, done and finished once for all; but a long series of acts—a work continuously pursued through an inconceivable lapse of time. It is another fact equally certain, that this work, as it has been pursued in Time, so also it is a work which has been pursued by Method. (218)

While the historicization of human invention and divine creation had made natural theological evidences more vulnerable to naturalistic reinterpretation, it also supported a natural theology which could assimilate evolution. While this historicization had turned words that had referred to static things or states, like 'creation, 'invention', 'construction', 'contrivance', or 'adaptation', into words referring to activities that happen through and across time, natural theology was able to make the transition by depending on the histories of invention's backward-facing confidence in personal and knowable origins combined with its forward-facing confidence in teleological development. 'Adaptation' as a process instead of a state did not necessarily cancel out natural theology's possibility, but pointed to its albeit fragile plausibility structure. So although historicizing invention served as a transitional phase from a creationist view of nature as static to an evolutionary view of nature as historically dynamic, it also offered resources to remake natural theology for those willing to claim them.

Natural Theology's Things, Natural Theology's Time

My interpretations of natural theology's relationship to the historicization of invention in this chapter may seem somewhat contradictory. I have suggested that the meanings of machines constructed by histories of invention related to the design argument in a number of inconsistent ways: they sustained it, made it vulnerable, supported an opposing and secular interpretation of the natural world, and enabled natural theology to assimilate evolutionary readings of nature. But the diversity and complexity of this relationship does not necessarily indicate incoherence in my argument. Instead it reflects the fracturing relationship between natural theology and one meaning of machines—and therefore the splintering of one pillar of design's plausibility structure. But even while that part of the structure was breaking down, natural theology and histories of technology had also already parted ways, registered in their totally divergent attitudes towards physical *things*.

As this project has traced, meanings of machines proliferated in the early nineteenth century through the literature of technology.[181] Whether positive or negative, each chapter focused on one meaning for machines and its relationship to design. Yet I have not yet brought these meanings together to see how their interactions impacted natural theology. In the final pages of this chapter, I would like to deal with the implications of the proliferation of technology's cultural meanings in early nineteenth-century Britain, complicating the cultural contours I have already traced. The emergence, growth, and branching of these meanings was not according to set patterns, but was unpredictable and inconsistent. New technologies could be either sublime or comprehensible. Machines could either threaten human agency or magnify it through the Promethean power they gave. Critics of the factory system decried machines as unnatural where supporters justified them as part of nature. Such contradictions were particularly difficult for other discourses dependent on the meanings of machines, like natural theology, to deal with. For which meaning did design's mechanical metaphors capture? These industrial texts created meanings of machines that were not inherently in tension, but became so when framed by natural theology.

Histories of invention offer an excellent place to observe the shaping force natural theology exerted on the offered meanings of machines—and to observe the damage natural theology could thus do to itself. Framed by design, tension between the content and form of histories of technology created contradictory meanings of machines which complicated the relationship between natural theology and its industrial plausibility structure. In content, these histories historicized technological things, but they also insisted that invention could be attributed to a personal inventor, that things indicated the persons behind them. So they supported natural theology, albeit of a progressive, evolutionary type. But in form, these histories told a different story by dividing the thing from its personal source, reflecting a habit of thought incompatible with natural theology.

The variability of mechanical meanings is evident in the formal construction of histories of invention. So far, each of my analyses of a genre within the literature of technology, from explications of steam engines to industrial travel narratives to mechanics textbooks to histories of invention, has assumed that each of those sets of texts had a singular and stable generic structure with generalized, but shared and identifiable, characteristics. But 'history' as a genre in the early nineteenth century was itself far from singular.[182] It could be

[181] On the rich and proliferating meanings of 'things' in the early Victorian period, see Freedgood, *Ideas*.
[182] On the varieties of 'history' as a genre through time, see Burrow; and in the nineteenth century, see Bann, *Clothing*

a book genre or a mode interpenetrating other genres, like encyclopaedia entries or journal articles. As a book genre, it was broad and forgiving, incorporating a numbers of narratives, methodologies, and structures.[183] Single texts often registered this heteroglossia: histories of invention brought multiple historiographies together, involving histories of the nation, the hero, the event, and the thing. They incorporate elements both from histories of civilizations like Gibbon's *Decline and Fall of the Roman Empire* and the it-narratives which tell the story of a single thing owned by multiple owners. Beyond the varieties of historiography, they also became near generic hybrids by incorporating forms and methodologies from other genres within the literature of technology—expositions, statistics, treatises, diagrams.[184]

Histories of invention split into sub-generic strands: histories of a single technology, histories of an industry, and biographical or autobiographical histories. The second and third are fairly stable, but the first is a battlefield of forms. Many 'histories' of the steam engine discussed in this chapter also appeared in chapter two as popular 'expositions' of the steam engine.[185] So which are they? Histories or expositions? Simply, they are both. They are generic hybrids in which the two modes or genres merge together, combining to determine the trajectory of the text. Nearly all begin with the historical frame which is interpolated by technical descriptions and diagrams or drawings of the specific invention they discuss. But as they advance, the historical frame recedes as the expository and descriptive mode begins to dominate the text.[186] Thus they are not so much carefully layered generic hybrids, but generic mutts with randomly combined characteristics.[187]

Not only does this combination fail to blend elegantly, but its two modes actually contradict each other, contending for control of the meanings of the things they package. The ambiguity of 'invention' registers this tension. The historical approach implicitly

[183] On history as borrowing 'protocols from other professional practices' (24), see Bann, *Inventions* 12-32.
[184] O'Connor has forwarded a similar project to mine here, tracking the 'generic plurality' (228), 'subtle generic continuum' (231), or 'generic fluidity' (232) of popular geological texts in the early nineteenth century, without calling them generic hybrids (*Earth* 228-261).
[185] Every text on the steam engine in chapter two reappears in this chapter, with the exception of Birkbeck's *The Steam Engine Theoretically and Practically Displayed* (1827) and Lardner's *Popular Lectures on the Steam Engine* (1828).
[186] These extended descriptive passages were enabled by the 'expanded descriptive apparatus' (Freedgood, *Ideas* 8) of the early nineteenth century and the growing interest in detailed description noticed by Wall.
[187] Fowler understands generic hybridity as when 'two or more complete repertoires are present in such proportions that no one of them dominates' (183). For a less mincingly taxonomic approach, see Frow, *Genre* 40-50, on 'generic complexity'. On the ways different genres are merged together in the transformations of genres, see Fowler 171-188; and on 'generic modulation', in which the elements of another recognizable genre are mined for the benefit of a different genre, see Frow, *Genre* 191-212. Histories of technology are thus generic mixtures someplace between hybridity and modulation in Frow's terms: they do not include complete repertoires of either genre, but neither is one subordinate to the other. Instead they resemble a failed hybrid in which the genres contradict each other.

characterized invention as an action done by a *person* in time while the expository approach implicitly characterized an invention as a *thing*. Where the historical guaranteed a person behind the invention, the expository was interested only in the physical invention itself. Form thus told a different story from content: as the expository edged out the historical, the thing eclipsed the people which these histories seemed so anxious to identify. The tension within this hybrid genre indicated an increasing disconnection between things and their makers. As the expository (with its focus on things) overwhelmed the historical (with its inference to people) these histories of the steam engine problematized the jump from thing to person that was necessary for natural theology to work. Their generic complexity registers a disruption of the mental process which natural theology both assumed and required: that things point beyond themselves. In the textual competition between narrative and description, between people and things, things win. Thus where machines had been passive in the content of these texts, they became agents in their formal structure.[188]

The thing's triumph over the person was hastened by the physical arrangement of these books, particularly by the relationship between text and illustration. The images ultimately lined up with the expository to induce a blinkered focus on things without reference to their makers. With a few exceptions, these texts include many images, from simple diagrams to detailed illustrations (Fig. 5.1). Of the hundreds of images in the histories of the steam engine, almost all are of machines or machines parts. In all the histories of invention I have listed, only three include portraits of inventors.[189] This numerical imbalance already suggests that images supported things in their contest with people. The content and style of the images of machines also signals their alignment with things. Many of them are historically specific, representing an engine or part made by a specific person at a specific moment and arranged alongside the narrative about its invention and the technical description of the invention. This impulse to visualize specific things grew out of engineering practice and out of the practices of popular scientific lecturers, who usually lectured from particular

[188] The formal structure of these texts thus interacts with the larger question of human agency in an industrial world discussed in chapter four. The human versus machine conflict was thus recapitulated in the literary form of the literature of technology.

[189] Baines includes portraits of Arkwright, Crompton, and Robert Peel; J. Williams includes an engraving of a memorial coin of Watt's head on his title page; Stuart includes twenty-one portraits of a variety of inventive contributors to the steam engine in *Historical and Descriptive Anecdotes of Steam-Engines*, in keeping with his biographical focus. The relative absence of portraiture from these texts is emphasized when put in context: portraiture played and continues to play an important role in shaping perceptions of science and medicine, see Jordanova. On the self-fashioning of scientists through visual strategies, including portraiture, see Fara, 'Framing'. Visual representations of inventors were not lacking in the larger historical context of the 1830s, but just missing from these texts. After all, national and political dignitaries met in 1824 to make plans for a statue of Watt to be placed in Westminster Abbey. On this meeting and later statues of Watt and other inventors, see MacLeod, *Heroes*.

objects, not on abstract concepts.[190] Where images were often subordinate to verbal description in some popular science texts, they played a more prominent role in the explanation of steam engines.[191] Their relative weight meant that they had significant power to influence the contest between the thing and the person in the text's content. These images of machines are sparing: they represent only the machine and its parts, omit environmental context, use shading just enough to make the image intelligible, and omit its human users or operators altogether.[192] Machines are represented without any shred of context—whether human, environmental, or historical. The images construct the reader's purpose as looking at and understanding the mechanical thing in itself and to look no further. The stubborn thingness of actual steam engines, even when buffered through these drawings, attempts to capture the reader's attention irrevocably. The invasive supremacy of the thing trumpeted by the images thus disrupts the historical narrative, abetting the focus on the thing set up by the expository mode. The presence of real machines in the early nineteenth-century visual field only reinforced this orientation toward things. In spite of their historical narratives connecting things with their inventors, the form and the relationship between text and image in these histories of technology implied the triumph of the technological thing as it drew attention away from the inventor and back into itself.

While equally focused on things, natural theology revealed a completely different attitude, continually reiterating and reinforcing the inference from thing to person. The distance between historicized technological things and natural theological things indicates the division between natural theology and certain meanings of machines constructed by the literature of technology. This divergence is evident in the relatively coherent formal structure of natural theology. Although scholars emphasize the variety and diversity of natural theology's cognitive content, it was surprisingly stable as a genre. Where histories of technology are generically complex, natural theology is surprisingly simple and constant, with an inherited generic form elastic and capacious enough to survive for several more centuries. Within a theological frame, the natural theological genre proceeded by stitching together detailed expositions of natural objects and then allowing the reader to do the bulk of the work to infer a designer. Here is a paradox. Histories of technology tried to combine two modes in an attempt to guarantee a link between things and their makers. That hybridity

[190] On drawing in engineering practice, see J. Brown. On objects in science lecturing and in exhibitions, see the essays collected in Fyfe and Lightman; Morus, 'Manufacturing', '"More"', 'Worlds'.
[191] On the privileging of words over images in popular geological writing in the early nineteenth century, see O'Connor, *Earth* 330-345. On their role in creating a public language for discussing machines, see chapter two.
[192] For a totally different nineteenth-century approach to the visual representation of technology which nearly always included environmental context and human beings, see Chew and Wilson; Freeman; Klingender.

ultimately unravelled that link. But natural theologies focused primarily on describing things and generally let the reader do the rest of the work to get to the maker. Natural theologians were supremely confident that readers, unless inflicted with an atheistic mental illness, would complete this equation. Some Bridgewater authors even understood the natural theologian's work as mere collection of things.[193] Even the more philosophically-informed authors assumed that unmediated things would produce conviction of design: for Whewell, 'examination of the material world' led to belief in the non-material (*Astronomy* 1), while for Bell 'If we select any object from the whole extent of animal nature, and contemplate it fully and in all its bearings, we shall certainly come to this conclusion: that there is evidence of design in the mechanical construction' (1). Only Roget recognized that the contemplative human could be 'overwhelmed by the multiplicity of objects, and lost amidst the complication of phenomena, he soon becomes dismayed by the magnitude and arduous nature of the investigation' (1: 17).[194] But Roget's emphasis on the 'inexhaustible variety of objects' functions rhetorically to heighten the sense of design when that 'endless diversity of phenomena' (1: 3) is resolved into order.

The texts' assembly matched the conviction that careful contemplation of things was a simple and unmediated route to the inference of a designer. Within the theological frame, the Bridgewater Treatises largely collect descriptions of a profusion of natural things, cabinets of curiosity bursting at the seams with the fecundity of the natural world. While Chalmers, Whewell, and Prout describe processes in a collected 1,533 pages, the rest of the treatises, and their 3,797 pages, primarily describe things (Table 5.2). Scholars have complained about this, calling natural theology 'an argument from exhaustion' (J. Robson 89).[195] But this thing-focus had intense power, both to activate the intuition to design and to encourage the scientific study of nature. Natural theology depended on the psychological power of things to lead its readers to knowledge of the designer. Indeed, natural theology needed material objects in order to differentiate between the material and immaterial and then to argue for the immaterial. While the cumulative profusion constantly threatened to break the bounds of the imposed order, any one individual thing was immensely powerful psychologically.[196] Even

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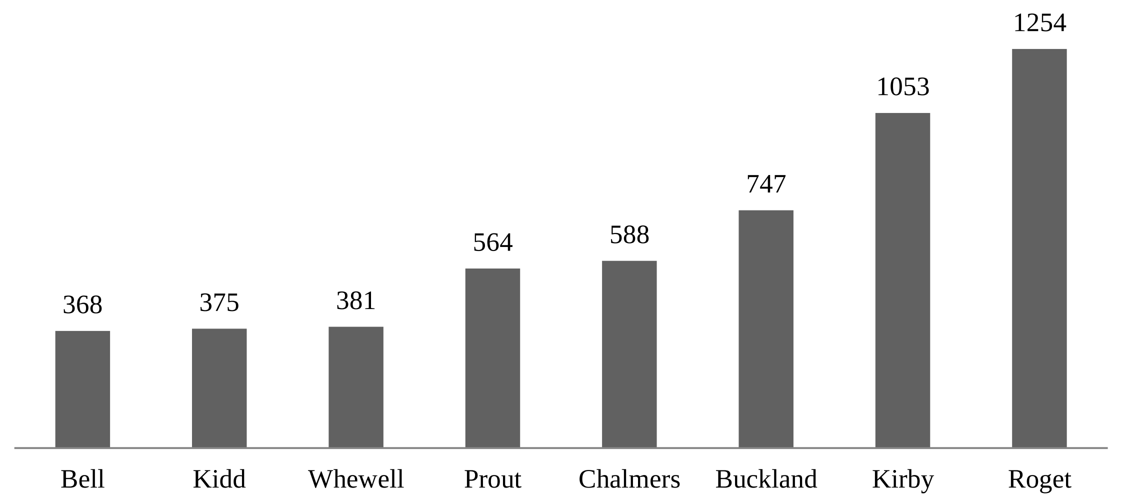
[193] Kidd vii; Prout xii. Powell complained that most recent natural theology, although popular, focused 'on mere accumulation of particular instances of design' (ix).
[194] See especially Roget 1: 10-16.
[195] While J. Robson complains about this common pattern as an unsophisticated 'movement from one example to another' (89), Jager suggests that natural theology's 'intellectual ambition leads away from careful philosophical delineation and towards a certain capaciousness' (2).
[196] Brooke and Cantor have argued that a major attraction of design argument was the 'visibility, incorrigibility and ubiquity of nature' (180), stimulating the imaginations of its readers (184-190).

Table 5.2 The Bridgewater Treatises by the [Page] Numbers



when they multiply that fecundity by historicizing it, the focus on a single and individual thing at a certain point in time works toward stability for they rarely show a thing in process of change. The focus on things thus implicitly suggested a stable essence that each thing expressed, bolstering design.

As with histories of technology, the images in natural theology reinforced its attitude toward things. The early treatises by Kidd, Chalmers, and Whewell have no images, but the later treatises contain many. Kirby includes seventeen plates divided between his two volumes, Bell incorporates a few scenes and then several small inset drawings, Roget saturates his with inset drawings of specimens, and Buckland devotes his second volume to sixty-nine plates, most of which are of specimens and a few of which are stratigraphic schematics of landscapes.[197] Most images are in the same style as those in the histories of invention: they are simple black-and-white drawings of specimens totally removed from any type of context (Fig. 5.3, 5.1). But the culture into which they fit gives them a different significance. These images participated in the naturalist tradition of collecting actual specimens.[198] Collections of images of specimens served as visual museums, giving people access to physical collections held in Paris or the United States. The images were connected not just with specific, concrete specimens, but they also

[197] Prout also includes a few non-representational chemical diagrams and a map. The importance of illustration to natural theology was established in Paxton's letterpress illustrations for Bell and Brougham's 1826 updating of Paley's *Natural Theology*.
[198] For the growing emphasis on the active study of nature in the field, see Gillespie, 'Natural'.

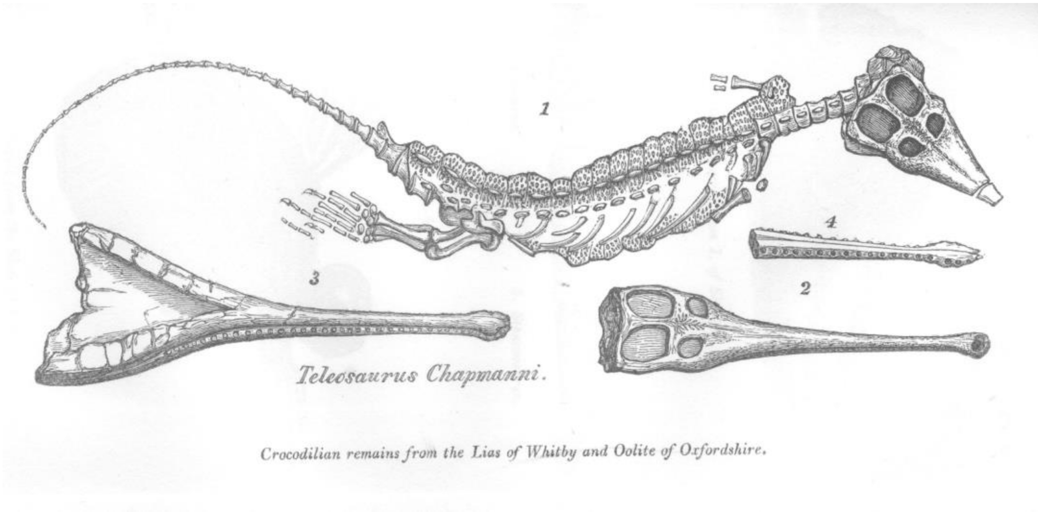


Fig. 5.3. ‘Teleosaurus Chapmanni’ from Buckland’s *Geology and Mineralogy* (2: Plate 25).

encouraged a tradition of amateur naturalists to collect specimens for themselves.[199] For the naturalist, as for Linnaeus, the ‘great globe’ was ‘a Museum, furnished forth with the works of the Supreme Being’ (Bell 10). These images thus expanded natural theology’s attachment to things by encouraging its readers to go out and collect even more real things out there which would lead them to knowledge of the designer. Thus not only were these images complicit in natural theology’s main narrative, but they expanded it beyond the boards and into the fields or forests near any reader in England.

If natural theological texts pointed outside themselves to the things of nature, histories of invention also pointed outside themselves to real technological things. The conflicting attitudes toward things in each genre were also matched by conflicting phenomenologies outside them. Natural theology was confident that its readers would experience natural things in such a way that they would delightedly make the inference to design and a designer. An entirely opposite phenomenology of technological things is reflected, perhaps not even constructed, by the triumph of description over narrative in histories of invention. In a time when the ‘visual manifestations of the industrial order were objects of commonplace remark’ (Morrell and Thackray 2), how people experienced machines became an urgent question. In chapter four, for example, I traced how critics of the factory system understood machine work as the absorption of the human into the machine, producing mentally-stunted and physically-deformed humans. Although rhetorical and interested, these texts indicate a

[199] On Ray’s illustrations as encouraging people to get out and study nature in the wild, see Gillespie, ‘Natural’ 40. The relationship between naturalist collection and natural theology stayed strong through the century, see Johnson. On amateur naturalism, especially at the seashore, and its natural theological frame as constructed by Philip Henry Gosse, see J. Smith, *Charles* 77-91.

similar phenomenology of machines to that in histories of invention: machines magnetically draw observers in. Devouring human agency, they also voraciously consume human attention. The technological sublime Carlyle experienced when looking over Birmingham in 1824 reflects the machine's cognitive monopoly.[200] He is awed by what he sees, and all his mental energy is consumed in contemplating the scene—not in thinking about it. The sound of a running steam engine, even when detached from the machinery it is designed to run, is so loud, so powerful, that it drives out any other thoughts from all but the most practised observer's head.[201] Massive black holes, technological things lose all reference beyond themselves, including the engineer. Thus the phenomenology of technology differs completely from natural theology's assumed phenomenology of nature.

Maybe, in the end, the real opponent of natural theology was not philosophical materialism, but matter itself—the Victorian obsession with stuff. Perhaps the growing obsession with shawls, crockery, top hats, and cotton accompanied by the phenomenology of the powerful Victorian technologies so ubiquitous in the machine hall at the Crystal Palace does as much to account for the trajectory of natural theology in the nineteenth century as the usual appeals to the Darwin and naturalism. Perhaps Victorian phenomenology rather than philosophy can explain how natural theology contracted from cultural centrality to cultural marginality in just a half a century. The intuition to design that so strongly persisted in Darwin's mind, the intuition that matter points to something beyond and different from itself, is disabled, not by philosophical attacks, but by a changing habit of thought that focuses solely on matter without making the intuitive step to something beyond it. Secularization is not necessarily philosophical, but psychological.

But if phenomenology, rather than philosophy, helps account for natural theology's cultural contraction, it also makes accounting for natural theology's continuance easier. Where consistency is a significant criterion of philosophy and the intellectual historians who study it, it is irrelevant when experience is the historical focus, allowing the student of nineteenth-century culture to become aware of rich, various, and contradictory meanings, structures of thought, and cultural formations evolving through that fecund century. And natural theology could survive because of this very richness, because new plausibility structures could grow anywhere. Although the meanings of machines I have traced in this project—comprehensibility, naturalness, passivity and predictability, and historicity—shifted

[200] See chapter two.
[201] One can just begin to re-enact this experience by watching the steam engine at work in the Energy Hall of the London Science Museum. See http://www.sciencemuseum.org.uk/objects/motive_power/1971-78.aspx, for images of the engine.

and changed, enough of the meanings for technology that were useful to natural theology persisted. Comprehensibility, passivity, and predictability persisted in the growing standardization of machines as well as the standardization of engineering education. The connection of machines with their makers was re-forged through the explosively popular genre of biographies of engineers and great inventors detonated by Samuel Smiles's *Life of George Stephenson*, published in 1857, conveniently two years before Darwin's *Origin*.[202] Natural theology also diversified its plausibility structure by incorporating the beauty of nature as evidence of design. This association of design with beauty instead of mechanism actually followed wider contemporary usage of 'design' to refer to the decorative arts taught at a growing number of design schools, beginning with the Government School of Design in 1837 after the *Report from the Select Committee on Arts and Manufactures* in 1835.[203] Yet the phenomenology of the machine limited the proliferation of meanings for machines and the diversification of natural theology which allowed it to persist. That phenomenology meant that natural theology could no longer depend on unmediated experience to produce inferences and intuitions, but had to carefully shape the process of experiencing and observing design.

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[202] Against Wiener's connection of industrial decline with the declining reputations of engineers in *English*, MacLeod has traced their high reputations right through the century (*Heroes*).

[203] For an aesthetic natural theology, see James Houghton Kennedy's *Natural Theology and Modern Thought* (1891). On aesthetic natural theology, see Brooke, 'Like'; Brooke and Cantor 163, 207-243. Brooke and Cantor point out particularly that God as artisan dies, but as artist was reborn after Darwin's *Origin*, particularly with George Tyrell (163). On natural theology as naturally an aesthetic category for looking at nature from the eighteenth century, see Harman, *Culture*. On the use of aesthetic appreciation of nature in theologies of nature, particularly in the work of Thomas Dick, see Astore 100-108.

On 'design reform' beginning in the 1830s to correct the perceived degeneracy of British taste, see Kriegel. What is surprising about Kriegel's work—and the work of others on nineteenth-century industrial design—is that they do not connect it with the other 'design'—natural theology.

CONCLUSION

At the beginning of his extraordinarily popular Bridgewater Treatise on geology, William Buckland imagines three explorers who arrive in different areas of Great Britain. One lands in Wales and characterizes Great Britain as a mountainous country inhabited by miners, a second explores the Midlands and sees the island as a fertile land dotted with manufactures, and a third arrives in Yorkshire and thinks it is a 'great cornfield, occupied by persons almost exclusively engaged in the pursuits of husbandry' (1: 2-3). Generalizing from a single region, they each get an incomplete vision of the entirety of Great Britain. Only when their observations are brought together can an accurate mapping of the island be achieved. Likewise, narrow academic disciplinarity in studies of nineteenth-century Britain have produced incomplete and inconsistent mappings of its landscape. Approaching the nineteenth century from different disciplinary landing points, scholars characterize it according to the topics, methodologies, and preoccupations of their disciplines. Historians of science describe it one way, literary critics another, and intellectual historians a third.

But with the recent championing of interdisciplinarity in the humanities, mappings of that fascinating century have been revised, becoming increasingly interested in the frontiers between those varied regions. In keeping with this movement, my survey of early nineteenth-century Britain's cultural landscape has explored two prominent but seemingly discrete topographies: technology and religion. Focusing on a newly emergent literature of technology and a natural theology with recently recovered popularity, I have approached this cultural landscape from different disciplinary regions—from literary studies, from the history of technology, from religious history, and from nineteenth-century studies. Yet each of these approaches has been to the same cultural mass, just as Buckland's travellers were all exploring the same land mass. But I have gone further than they did to explore the borderlands between literature, religion, and technology, using the literary forms of metaphor and genre as my compass.

Travelling in uncharted scholarly territory with mechanical metaphors as my lodestar, I have hypothesized and then demonstrated that religion, technology, and literature were not separate cultural islands, but contiguous topographies in early nineteenth-century Britain. Dependent on the mechanical design analogy, natural theology was the geographical feature where these topographies met and thus the area on which I have concentrated. I have argued that design's incredible popularity in the 1830s was supported by an industrial plausibility structure built on the meanings of machines. Four generic forms of an emergent literature of technology—expositions, industrial travel narratives, mechanics textbooks, and histories of invention—constructed meanings for machines that made design a plausible and attractive way of thinking. Chapter two suggested that natural theology internalized the explanatory practices of expositions of steam engines, depending on the comprehensibility of design they established. Chapter three traced how industrial travel narratives and taxonomies of machines reinforced the design analogy by guaranteeing the similarity between nature and machines. Chapter four explored how solutions to problems of industrialism offered by mechanics textbooks also provided a solution to the inherited theological problem of divine action in a law-bound world. These three chapters argued for positive and reinforcing relationships between natural theology and the literature of technology, but chapter five changed tack by investigating a meaning for machines which complicated natural theology's plausibility structure. It argued that histories of technology created a historicized model of invention that both enabled natural theology's success and prepared for its cultural contraction

The strength of my project has been in its interdisciplinarity—in its exploration of the borderlands between disciplinary and historical regions. But what I have found in this scholarly expedition also compels reconsideration of established disciplinary mappings, assumptions, and queries in studies of nineteenth-century Britain. Once we recognize that natural theology and the meanings of machines are features of the same topography, our perspective on the wider cultural landscape of nineteenth-century Britain must be revised. Received scholarly mappings have consistently emphasized technology and religion as two of the most significant features of this topography. While I do not dispute their significance, I will conclude this thesis by suggesting ways that my work changes the way we look at these cultural massifs.

Traditionally, religion has been seen as one of the most important topics to and for nineteenth-century Britain. A single scholarly metanarrative with multiple sub-plots dominates this perspective: in the process of secularization, the British lost their faith over the course of the century. This narrative attributes secularization and the 'crisis of faith' primarily to an imagined unholy alliance between German Higher Criticism and science, especially Darwin's *Origin of Species*. And it assumes that British Christianity was an inherited, static, and intellectually-faulty system too brittle to respond to contemporary intellectual, scientific, and cultural 'advances'. But, along with Brooke who demonstratively downplays the *Origin*'s significance and with recent critics of the secularization narrative, my work has shown that natural theology was a culturally sensitive apologetics that responded to the needs and discourses of its time. It was plausible and attractive because it drew on contemporary ways of thinking about human design to conceptualize divine design, thereby remaining culturally germane.

Beyond questions of science, Biblical hermeneutics, and secularization, my project has pointed to other factors, particularly technology, that influenced the shape and development of nineteenth-century Christianity. Mapping religion's contours with reference only to science or Higher Criticism inherently simplifies the complexity of culture and of its dominant discourses. It makes science and Higher Criticism the heroes of secularization. Instead, my project suggests that secularization fails to account for the intellectual and popular vibrancy of 1830s natural theology while it also fails to register the impact of technology on British religious discourse. Re-orienting ourselves on religion using technology as a landmark, we see that natural theology was alive, culturally-responsive, and powerful—hardly Darwin's straw man. Nineteenth-century religion was thus not the last vestige of an outdated, ossified worldview finally destroyed by science and critiques of Biblical authority, but a thriving and dynamic cultural force sustained by a wide cultural network and which both responded to and shaped that network.

Where traditional scholarly maps of nineteenth-century religion reflect its deterioration, such maps register an opposite trajectory for the other cultural landmark which my project charts: technology, which grew ever more complex and powerful. Scholars in the history and philosophy of technology have generally recognized that technology is not outside of culture, but part of it. Yet this perspective has largely been ignored by scholars who approach the nineteenth century from the humanities, particularly literary studies. Such scholars have implicitly followed Raymond Williams in opposing culture and industry, literature and technology. They cite the techno-criticism, if not technophobia, of the great Victorian sages and authors, like Carlyle, Dickens, Ruskin, Arnold, and Morris, while they ignore Carlyle's celebration of 'Captains of Industry' and George Eliot's significant financial investment in railways. In such a view, there is no place for technology in culture, defined by Arnold as 'the best which has been thought and said' (viii). Instead, my work has shown that not only was technology part of culture, but that technology and literature were deeply interconnected rather than inherently opposed in the nineteenth century and that this relationship had widespread effects on other discourses, particularly natural theology. Technology was thus not an alien force threatening the human in the nineteenth century, but a complicated dimension of what it meant to be human—and what it still means to be human today.

This final jump from the nineteenth to the twenty-first century may seem like a stretch to some. For what does the nineteenth century have to do with today? How does nineteenth-century religion, let alone apologetics, matter? Why do such contextually-specific meanings of machines matter? The historical narratives which I critiqued in the last three paragraphs actually have as much to do with today as they do with the nineteenth century. Why have these features been mapped the way they have? Why do we see nineteenth-century technology and religion the way we do? Partly because what we see is shaped by our technologies of observation—by the assumptions that structure our methodologies. Identifying our academic culture as thoroughly secular and rational against the superstitions of religion, we have Whiggishly constructed a history that explains—and justifies—how we got this way, lionizing those like Darwin, Strauss, and Feuerbach who contributed to secularization. But if history bears another description, if religion in the nineteenth century was not a crumbling and antiquated structure but a living, dynamic, and relevant force, then we must ask ourselves if our culture is really as secular as we think it is and if religion is really dead.

Similarly, the opposition between technology and culture is assumed by many academics within the humanities today and then projected onto the nineteenth-century past. Literature and science were long held to be the 'two cultures' in opposition, but that antagonism has faded recently as scholars have recognized the intertwining of the two. But I believe that C.P. Snow's categories failed to characterize culture at large, for the study and practice of 'science' and 'literature' are largely academic disciplines isolated to the ivory tower. Thus while science and literature have come closer to each other even in today's climate of competition for funding within academia, technology and literature remain the true antagonists to many academics. It is an antagonism between doing and thinking, between utilitarianism and beauty, and—dare I say it—between industry and academia. Feeling marginalized in an educational system oriented around preparing students for the job market instead of teaching them how to think or how to pursue and create knowledge, humanities scholars run the risk of dividing themselves from the leadership they could provide by bitterly opposing the doers and the doing. But my project has recognized that literature and technology—culture and technology—have not and need not be so divorced from each other. Instead, in expanding our understandings of technology as a cultural phenomenon, of the relationship between literature and technology, and of nineteenth-century British culture, I have shown that the way technology is talked about matters. Ultimately, I hope this claim can provide a point-of-contact between the humanities and contemporary techno-culture, between literary scholars and engineering professionals as they work through what and how technology means as we forge a path into an ever-technologized future.

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