Characterisations in Britain of Isaac Newton's Approach to Physical Inquiry in the *Principia* between 1687 and 1713

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Abstract

In order to gain a better understanding of the impact and circulation of the first edition of the *Principia*, we offer an analysis of public perceptions in Britain of Isaac Newton's approach to physical inquiry in the *Principia* between the appearance of its first and second editions, in 1687 and 1713, respectively. We treat Newton's readers as actors with distinctive scholarly backgrounds and interests rather than as followers or popularisers of a "Newtonian philosophy," a label we find to be largely absent in the historical record before 1713, when it was purposefully used by Roger Cotes in his preface to the second edition of the *Principia*. Through our survey, we gain considerable insight into how Newton's readers characterised the *Principia* and its author. We establish that British readers of the first edition of the *Principia* ascribed a relatively stable and interrelated number of characteristics to Newton's natural philosophical approach, although different readers emphasised different things. We also show that the most detailed accounts of Newton's natural philosophical approach were, not surprisingly, given in polemical contexts. We find that it is only at the very end of this period, and in polemical contexts, that the notion of a "Newtonian philosophy" with a specific and pathbreaking approach to physical inquiry arose.

Keywords

"Newtonian philosophy" – Isaac Newton – Newton's approach to physical inquiry – first and second edition of the *Principia* – *Optice* (1706)

1 Introduction

In this essay, we are concerned with characterisations of Isaac Newton's (1642–1727) approach to physical inquiry in his *Philosophiae naturalis principia mathematica*. Particularly, we discuss perceptions in Britain between the publication of the first edition in 1687 and the second in 1713. As is shown by ongoing scholarship – and further confirmed by our research – the early circulation of the *Principia* was much larger, certainly in the British Isles, than is commonly assumed, and is thus in need of further scrutiny.¹ Our study is based primarily on publicly available material, such as printed books, textbooks, journal articles, and occasionally poems, at the expense of unpublished material.

The British case is of particular interest, since earlier scholarship has established that it was in the British Isles that Newton's ideas were rapidly connected to philosophical debates on matter, motion and gravity, and how these related to God. It has also been argued that the application of a particular Newtonian approach to other branches of learning was being promoted by the early 1690s.² The period between 1687 and 1713 is also of particular interest for reasons internal to the *Principia*. While readers of the first edition agreed that it was highly successful and set a standard for how to proceed in physical inquiry, the book actually contained few explicit statements on its approach. By consequence, readers who wished to discuss that approach – and our survey shows that many of them did – had to make interpretative choices of their own. More comprehensive expositions of the approach in the *Principia* from Newton's own hand became available only with the appearance of the 1706 Latin rendition of the *Opticks*. There Newton provided a discussion of the method of analysis and synthesis in the penultimate paragraph of *Quaestio* 23, as will be discussed in more detail in section 4 below. Furthermore, in the

1 Many details on the early distribution of the *Principia* have recently been unearthed by Mordechai Feingold and Andrej Svoboda, "A Preliminary Census of Copies of the First Edition of Newton's *Principia* (ed. 1687)," *Annals of Science*, 77 (2020), 253–348; here they offer a census of copies of the first edition of the *Principia* that confirms that its circulation was larger than previous studies have asserted.

2 See, e.g., Anita Guerrini, "The Tory Newtonians: Gregory, Pitcairne, and Their Circle," *Journal of British Studies*, 25 (1986), 288–311; Simon Schaffer, "Newtonianism," in *Companion to the History of Modern Science*, eds. Robert Olby, Geoffrey Cantor, John Christie and Jonathan Hodge (London, 1990), 610–626; and Larry Stewart, *The Rise of Public Science: Rhetoric, Technology and Natural Theology in Newtonian Britain, 1660–1750* (Cambridge, 1992). We have analysed the debates on gravity and its relation to God in another paper: Steffen Ducheyne and Jip van Besouw, "Readers of the First Edition of the *Principia* on the Relation between Gravity, Matter, and Divine and Natural Causation: British Public Debates, 1687–1713," *Centaureus*, 63 (2021), 381–395, and therefore leave those debates aside here.

second edition of the *Principia*, we find a new editorial introduction, written by the brilliant young Plumian Professor, Roger Cotes (1682–1716), the *regulae philosophandi*, and Newton's own General Scholium. These texts provided readers with valuable information on the methodological orientation of the *Principia*, its major accomplishments, and its relation to other natural philosophical schools or approaches.³

A pivotal element of the editorial preface was Cotes' presentation of Newton's natural philosophy as fundamentally breaking, yet on par with, the natural philosophies of the Scholastics and the Cartesians.⁴ Cotes argued explicitly that the *Principia* offered a particular natural philosophical approach or a way of "philosophising," for which he used the term "the Newtonian philosophy [NEWTONIANAM [...] Philosophiam]."⁵ We have found that no one before Cotes used this terminology to refer to Newton's natural philosophical approach. To the best of our knowledge, fifteen titles make use of the adjective "Newtonian(us)" in the period under consideration. Close reading points out that these titles used the adjective to refer to Newton's mathematics, physics, or astronomy, or to the principle of gravitational attraction, but not to a

3 For discussion of the relevant changes with respect to the first edition of the *Principia*, see I. Bernard Cohen, *Introduction to Newton's 'Principia'* (Cambridge, MA, 1971); Larry Stewart, "Seeing through the Scholium: Religion and Reading Newton in the Eighteenth Century," *History of Science*, 34 (1996), 123–165; Stephen D. Snobelen, "God of Gods, and Lord of Lords': The Theology of Isaac Newton's General Scholium to the *Principia*," *Osiris*, 16 (2001), 169–208; Alan E. Shapiro, "Newton's 'Experimental Philosophy,'" *Early Science and Medicine*, 9 (2004), 185–217; Steffen Ducheyne, "*The Main Business of Natural Philosophy*": Isaac Newton's *Natural Philosophical Methodology* (Dordrecht, 2012), 170–174; and Chris Smeenk and Eric Schliesser, "Newton's *Principia*," in *The Oxford Handbook of the History of Science*, eds. Jed. Z. Buchwald and Robert Fox (Oxford, 2013), 109–165.

4 See Isaac Newton, *The Principia: Mathematical Principles of Natural Philosophy. A New Translation by I. Bernard Cohen, Anne Whitman; Assisted by Julia Budenz; Preceded by A Guide to Newton's Principia by I. Bernard Cohen* (Berkeley, CA, 1999), 385–386; Isaac Newton, *Philosophiae naturalis principia mathematica; editio secunda auctior et emendatior* (Cambridge, 1713), *Editoris praefatio*, b2–b2v, where Cotes divided those who have treated "physica" into three classes, of which the first are the Peripatetics, the second those who believe that "matter is homogeneous [Materiam universam homogeneam esse]," while their foundations are a "romance [Fabulam]," while the third "base their philosophy on experiments [qui Philosophiam scilicet Experimentalem profitentur]." See, furthermore, Newton, *The Principia*, 393; idem, *Principia* (ed. 1713), *Editoris praefatio*, c2, where Cotes denigrated those defending "Cartesian doctrines" and subsequently introduced the phrase "Newtonian philosophy." We have slightly adapted the translations found in Newton, *The Principia*, for clarity. For other works cited, translations are our own except when otherwise noted.

5 Newton, *The Principia*, 393; idem, *Principia* (ed. 1713), *Editoris praefatio*, c2.

particular natural philosophical approach.⁶ Here, as elsewhere, we base our findings on our comprehensive analysis of the relevant primary material, which we have collected through a combination of conventional means and digital searches.⁷

While readers of the second edition of the *Principia* would thus encounter relatively clear statements on its approach, the first edition gave far less explanation of methodological matters. What our survey reveals is that even though readers in Britain did not refer to a unique Newtonian method, their characterisations of Newton's natural philosophical approach single out a relatively stable and recognisable set of features, although, as might be expected, different readers emphasised different things. In each of the sections that follow, we identify a feature that became used by readers of the first edition of the *Principia*, to characterise Newton's natural philosophical approach. The first

6 The earliest uses of the adjective "Newtonian" in the English language are detailed by one of us in a separate paper, Steffen Ducheyne, "Early and Earliest Uses of the Word 'Newtonian,'" *Notes & Queries*, 67 (2020), 483–485. Besides the seven titles mentioned in that paper falling within the scope of the current paper, "Newtonianus" or one of its declensions is used in eight other British publications appearing in Latin. In three cases, the adjective refers to Newton's mathematics, namely Nicolas Fatio de Duillier, *Lineæ brevissimi descensus investigatio geometrica duplex* (London, 1699), 19; John Craig, "Epistola ad editorem continens solutionem duorum problematum," *Philosophical Transactions of the Royal Society of London*, 22 (1701), 746–745, at 746; and John Keill, *Introductio ad veram physicam* (Oxford, 1702), 95. In the others, it refers to Newton's physics and astronomy, namely Archibald Pitcairne, *Dissertationes medicae* (Rotterdam, 1701), 80; John Keill, "Joannis Keill ex æde Christi Oxon. A.M. epistola ad Cl. virum Gulielmum Cockburn, medicinæ doctorem. In qua leges attractionis aliaque physices principia traduntur," *Philosophical Transactions of the Royal Society of London*, 26 (1708), 97–110, at 99; John Freind, "Praelectionum chymicarum vindiciae, in quibus objectiones, in Actis Lipsiensibus anno 1710. mense Septembri ...," *Philosophical Transactions of the Royal Society of London*, 27 (1711), 330–342, at 331; William Whiston, *Praelectiones astronomicae Cantabrigiae in scholis publicis habitae* (Cambridge, 1707), passim; and idem, *Praelectiones physico-mathematicae Cantabrigiae in scholis publicis habitae* (Cambridge, 1710), passim.

7 In particular, we have collected our corpus of primary material in two ways. First, we have scrutinized existing literature on the early British readers of Newton. Second, we have used online tools such as Early English Books Online <eebo.chadwyck.com>, Eighteenth Century Collections Online <find.gale.com/ecco>, the search tool provided by The Royal Society <https://royalsocietypublishing.org>, and Google Ngrams <books.google.com/ngrams>, to complement the corpus with works not taken into account in the literature. We have thus found some 130 relevant titles, from which we cite selectively in what follows. In using digital tools, we have searched for appearances of "Newton," "Newtonus" and its cognates, "Newtonian," "Newtonianus" and its cognates. Although we cannot claim completeness due to the limits of the digital tools used and the fact that there might be unattributed reactions to Newton's work not discussed in previous studies, we believe our corpus is at least representative for the public debate we address in this essay.

three of these features are its mathematical nature, its neutrality with regard to the cause of gravity, and its reliance on observations and experiments. All of these features were used to set Newton's approach apart from approaches based on hypotheses. We will discuss this steering away from speculation and hypotheses as the fourth feature by which Newton's approach was characterised. In these sections, we will restrict ourselves to the most relevant cases, while referring to others in the footnotes. In the concluding section, we reflect on the implications of our survey.

2 Newton's Approach to Physical Inquiry in the *Principia* (1): The Use of Mathematics

Late seventeenth and early eighteenth-century readers of the *Principia* were baffled by its technicality. This is true even for trained mathematicians, who nevertheless anticipated and then read the book with much excitement.⁸ The first edition of the *Principia* presented itself to them as a highly complex web of definitions, laws, lemmas, propositions, corollaries, problems, scholia, and hypotheses, exhibiting a plethora of oftentimes highly sophisticated mathematical techniques and procedures. It was therefore daunting for them to understand Newton's approach to physical questions.⁹ Newton, moreover, offered relatively few clues that could help the reader in understanding it.¹⁰ It

8 See, for instance, the following letters collected in H. W. Turnbull et al., eds., *The Correspondence of Isaac Newton*, 7 vols. (Cambridge, 1959–1977), vol. 2: Gregory to Campbell, 2 February 1686/7, 463; Fatio de Dullier to Huygens, 14 June 1687, 475–477; Gregory to Newton, 2 September 1687, 484; Craig to Campbell 29 December 1687, 501. Various members of standing in the Royal Society, such as Wren, Wallis, Hooke, and Halley, themselves attacked some of the issues discussed in the *Principia* with sophisticated mathematical techniques. From the lack of their commentary on the *Principia*'s methods, we assume that these members approved of, and were not surprised by, its mathematical approach.

9 The methodology of the *Principia* has been fully grasped only in the last decades. It was explicated for the first time in I. Bernard Cohen, *The Newtonian Revolution, with Illustrations of the Transformation of Scientific Ideas* (Cambridge, 1980), and further explored in, for instance, George E. Smith, "The Newtonian Style in Book II of the *Principia*," in *Newton's Natural Philosophy*, eds. Jed Z. Buchwald and I. Bernard Cohen (Cambridge, MA, 2001), 238–313; idem, "The Methodology of the *Principia*," in *The Cambridge Companion to Newton*, eds. I. Bernard Cohen and G. E. Smith (Cambridge, 2002), 138–173; William L. Harper, *Isaac Newton's Methodology: Turning Data into Evidence about Gravity & Cosmology* (Oxford, 2011); and Ducheyne, *The Main Business of Natural Philosophy*.

10 For such sparse clues, see Newton, *The Principia*, 381–383 [preface], 408 [comment to definition 8], 588–589 [scholium to Section 11], 793 [introduction to Book III].

was clear to readers of the *Principia*, however, that it made exhaustive use of mathematics and for that reason it seemed to many of them to have achieved certain, demonstrative knowledge. Accordingly, an image was created of the *Principia* as a work heavily based on mathematics.

This, exactly, was what was argued in a discourse on gravity presented to the Royal Society in 1686, by the astronomer Edmond Halley (1656–1742). While first listing many of those who had speculated on its cause, Halley asserted that many discoveries about gravity had been

made out by *Mathematical demonstration* [...] by the accurate diligence of *Galilaeus, Torricellius, Hugenius*, and others, and now lately by our worthy Country-man Mr. *Isaac Newton*, (who has an incomparable *Treatise of Motion* almost ready for the Press).¹¹

Halley, thanks to whose monumental efforts Newton embarked on the *Principia*, got the Royal Society to approve the book, covered the printing costs, and started an energetic campaign to make the work known across Europe.¹² In the ode to Newton, a text full of hyperbolic praise published alongside the *Principia*, Halley again singled out its mathematical nature as the key to its success:

Things which so often tormented the minds of ancient Sages, and which fruitlessly vex the Schools with raucous disputation, we perceive in our path – the cloud being dispelled by Mathematics. No longer does error oppress doubtful mankind with darkness: the keenness of a sublime Intellect has allowed us to penetrate the dwellings of the Gods and to scale the heights of Heaven.¹³

In a pre-publication review of the *Principia*, published anonymously in the *Philosophical Transactions* in 1687, Halley repeated this point, emphasising that Newton's "great skill in the old and new Geometry [...]" has enabled him

11 Edmond Halley, "A Discourse Concerning Gravity," *Philosophical Transactions of the Royal Society of London*, 16 (1686), 3–21, at 6.

12 See Cohen, *Introduction*, 47–62, 130–142 on Halley's role in coaxing Newton into writing the *Principia* and in editing the work. See also Feingold and Svorenčík, "Census," 253–260 on Halley's role in circulating the *Principia*.

13 Quoted from W. R. Albury, "Halley's Ode on the *Principia* of Newton and the Epicurean Revival in England," *Journal of the History of Ideas*, 39 (1978), 24–43, at 27.

to master those Problems, which for their difficulty would have still lain unresolved, had one less qualified than himself attempted them.”¹⁴

Similarly, in his anonymously published review of the *Principia* in the Amsterdam-based *Bibliothèque universelle et historique*, the philosopher John Locke (1632–1704), also a Fellow of the Royal Society, observed that Newton “not only used the principles of the geometers in the explanation of physics, but even followed their method” by opening the *Principia* with the definitions and the laws of motion.¹⁵ By following the rules of geometry, Locke argued, works in mechanics could gain “all the exactitude and perfection that mathematicians are capable of imagining.”¹⁶ Five years later, in his *Some Thoughts concerning Education* (1693), he added that

the incomparable Mr. Newton has shewn [in the *Principia*] how far Mathematicks, applied to some Parts of Nature, may, upon Principles that matter of fact justifie, carry us in the knowledge of some, as I may so call them, particular Provinces of the incomprehensible Universe.”¹⁷

In his *Praelectiones astronomicae* (1707), which sought to explain Newton's astronomical contributions to Cambridge students, William Whiston (1667–1752), Newton's successor as Lucasian Professor of Mathematics, underscored the uniqueness of Newton's “stupendous” *Principia*, asserting that Newton “looked over the boundaries [of] mathematics” and that he had “submitted

14 [Edmond Halley], “Review of *Philosophiae naturalis principia mathematica*,” *Philosophical Transactions of the Royal Society of London*, 16 (1687), 291–297, at 291. Praise voicing Newton's exceptional mathematical qualities were not uncommon; see, e.g., John Keill, *An Examination of Dr. Burnet's Theory of the Earth. Together with Some Remarks on Mr. Whiston's New Theory of the Earth* (Oxford, 1698), 16–17: “the most Ingenious and Incomparable Mr. Newton, by his great and deep skill in Geometry, has shewed [...] that there are no vortices.” Other sources referring to Newton's mathematical approach include Edward Stillingfleet, *Origines sacrae: Or a Rational Account of the Grounds of Natural and Reveal'd Religion* (Cambridge, 1702 [seventh edition, first edition 1662]), 125 of the separately numbered annex, and John Harris, *Lexicon Technicum: Or, an Universal English Dictionary of Arts and Sciences*, vol. 1 (London, 1704), [a4].

15 [John Locke], “Review of the *Philosophiae naturalis principia mathematica*,” in *Bibliothèque universelle et historique*, 8 (1688), 436–450, at 437: “Non seulement l'Auteur se sert des Principes de Geometres, pour l'explication de la Physique, il a même suivi leur méthode; posant avant qu'entrer en matieres plusieurs définitions & axiomes touchant le mouvement.”

16 Ibid., 436: “Si ceux qui travaillent dans les Méchaniques entendoient parfaitement les regles de la Géometrie [...] ils pourroient donner à leur Ouvrages toute l'exactitude & la perfection que les Mathématiciens sont capables d'imaginer.”

17 [John Locke], *Some Thoughts Concerning Education* (London, 1693), 232.

the celestial universe to his geometry.” Whiston added that the “philosophical world” had never seen an equal to Newton.¹⁸ The mathematical nature of the *Principia* and the laws it expounded also found its way into poetry. In *Creation. A Philosophical Poem. Demonstrating the Existence and Providence of God* (1712), the English physician Sir Richard Blackmore (1654–1729), known for his epic poems, wrote:

The Masters form'd in *Newton's* famous School,
Who do's the Chief in modern Science Rule,
Erect their Schemes by Mathematick Laws,
And solve Appearances with just Applause.¹⁹

Blackmore thus named Newton as heading a school, one among many others, in explaining the phenomena of the heavens. To the best of our knowledge, his is the first publication that asserted the existence of such a school.

The *Principia's* geometrical approach was also mentioned in works published by two Scottish physicians, namely in Archibald Pitcairne's (1652–1713) *Dissertatio de motu sanguinis per vasa minima* (1693), in which it was promoted as a valuable tool to uncover “beyond doubt and more easily the forces and properties of bodies of use in medicine,” and in George Cheyne's (1672–1743) *A New Theory of Acute and Slow Continu'd Fevers* (1701), in which Cheyne, Pitcairne's student, explained that “all the great, visible, constant and uniform *Phenomena* of Nature” are “accounted for, from rigorous Geometry, by that stupendiously Great Man, Mr. *Newton*.”²⁰ Cheyne underscored in his later *Philosophical Principles of Natural Religion* (1705) that

18 Whiston, *Praelectiones astronomicae*, 3–4: “Mathematica Newtonus vester mirum in modum dilataverit; & conatu inaudito universa coelorum systemata calculo suo Geometrico submisit: *Philosophiae naturalis principia Mathematica*, Opus plane studendum; cui nihil simile aut secundum orbis philopichus unquam vidit.” On Whiston, see Stephen D. Snobelen, “William Whiston, Isaac Newton and the Crisis of Publicity,” *Studies in History and Philosophy of Science*, 35 (2004), 573–603.

19 Richard Blackmore, *Creation. A Philosophical Poem. Demonstrating the Existence and Providence of God* (London, 1712), 86.

20 Archibald Pitcairne, *Dissertatio de motu sanguinis per vasa minima*, respondent: Georgius Hepburne (Leiden, 1693), C: “certius faciliusque vires et proprietates corporum Medico usui”; [George Cheyne], *A New Theory of Acute and Slow Continu'd Fevers; [...] Together with an Essay Concerning the Improvements of the Theory of Medicine* (London, 1701), in the separate *Essay*, 24. On Pitcairne, see Anita Guerrini, “Archibald Pitcairne and Newtonian Medicine,” *Medical History*, 31 (1987), 70–83; on Cheyne, see eadem, *Obesity and Depression in the Enlightenment: The Life and Times of George Cheyne* (Norman, OK, 2000).

[a]ll the Attempts of others before Mr. *Newton*, to explain the regular and constant *Appearances* of Nature, were most of 'em *Ungeometrical*, and all of 'em so inconsistent or unintelligible, that it was hard to allow their *Postulata* as to conceive the thing which they pretend to account for from them.²¹

Another physician who took inspiration from Newton was Jeremiah Wainwright (b. 1673) from Yorkshire, who in *A Mechanical Account of the Non-Naturals* (1707) observed that “*all the Philosophy that has yet appear'd in the World, is no better than Trifling Romance, except what hath been writ by the famous Sir Isaac Newton, and some few others, who have built their Philosophical Reasonings upon Mathematical Principles.*”²² As these cases show, Newton's mathematical approach was frequently portrayed as a means to establish certain knowledge, and was occasionally contrasted to speculative approaches.

Exceptionally, Newton's approach was criticised by British authors for being excessively mathematical, but these reactions represented a minority. An example is the Norfolk-based writer and lawyer Roger North (1653–1734), who developed an interest in natural philosophy. In one of his private manuscripts, titled “Newton” and probably composed around 1705, North stated that Newton's work is “compleat in the mathematick way, but in phisicks[,] barbarous,” calling Newton's notion of mutual attraction “more precarious then any of the peripatetick traine.”²³ One of the few published statements that took a similar approach came from the Cambridge philosopher Robert Greene (1678?–1730), a fellow and tutor at Clare Hall. In his *The Principles of Natural Philosophy* (1712), which argued that natural philosophy was in need of an entirely new set of principles, Greene argued that Newton's mathematical method did not establish certain knowledge, because his mathematical demonstrations in the *Principia* depended “upon the Definitions, the Laws of Motion, and the Three first Sections express'd in Book the First.” In other

21 George Cheyne, *Philosophical Principles of Natural Religion: Containing the Elements of Natural Philosophy, and the Proofs for Natural Religion, Arising from them* (London, 1705), ch. 2, 16.

22 Jeremiah Wainwright, *A Mechanical Account of the Non-Naturals: Being a Brief Explication of the Changes made in Human Bodies, by Air, Diet, &c.* (London, 1707), A2v, which built upon ideas from Richard Mead, *De imperio solis ac lunæ in corpora humana et morbis inde oriundis* (London, 1704), which we mention below.

23 Cited in Jamie C. Kassler, *Seeking Truth: Roger North's Notes on Newton and Correspondence with Samuel Clarke c.1704–1713* (Farnham, 2014), 73–74. On the dating of this manuscript, see *ibid.*, 63–64.

words, according to Greene, Newton's natural philosophy was hypothetical, and its mathematical approach distracted us from perceiving this clearly.²⁴

3 Newton's Approach to Physical Inquiry in the *Principia* (11): Neutrality Regarding the Cause of Gravity

The first edition of the *Principia* contains a number of passages in which Newton stated that he would not deal with the, as yet unknown, cause of gravity. In the final paragraph of his comment to Definition 8, Newton pointed out that when using the terms "attractions and impulses," he was "considering these forces not from a physical but only from a mathematical point of view" and was not "defining a species or mode of action or a physical cause or reason," or "attributing forces in a true and physical sense to centers."²⁵ In the scholium to Section 11 in Book I, Newton similarly stated:

I use the word "attraction" here in a general sense for any endeavor whatever of bodies to approach one another, [...] considering in this treatise not the species of forces and their physical qualities but their quantities and mathematical proportions, as I have explained in the definitions.²⁶

Newton's neutrality with respect to the cause of gravitation was picked up and discussed widely and became an important feature of its image.²⁷ In his *Introductio ad veram physicam* (1702), John Keill (1671–1721), a student of the mathematician David Gregory (1659–1708) at both Edinburgh and Oxford, repeated the comment to Definition 8 almost verbatim. Keill started to lecture on natural philosophy in Oxford in 1697, publishing part of his lectures as the *Introductio*. Keill stated that with terms such as "attraction" he did not define "a true or physical cause, or a mode of action."²⁸ He underscored that he did

24 Robert Greene, *The Principles of Natural Philosophy* (Cambridge, 1712), 113–114. For further discussion of Greene's campaign against Newton, see John Gascoigne, "Politics, Patronage and Newtonianism: The Cambridge Example," *The Historical Journal*, 27 (1984), 1–24, at 23.

25 Newton, *The Principia*, 408; idem, *Philosophiae naturalis principia mathematica* (London, 1687), 5.

26 Newton, *The Principia*, 588; idem, *Principia* (ed. 1687), 191–192.

27 Besides the titles mentions in what follows, see Harris, *Lexicon*, under "attraction"; and [anon.], *The British Apollo. Or, Curious Amusements for the Ingenious*, vol. 1 ([London], 1708), 21 May–26 May, [p. 2]. Definition 8 was also paraphrased in Whiston, *Prælectiones physico-mathematicæ*, 40.

28 Keill, *Introductio*, 3: "non quod his vocibus veram causam seu rationem physicam, & modum actionis definimus." On Keill, see Anita Guerrini and Jole R. Shackelford, "John

not consider the cause of gravity, adding that “if the true causes are hidden from us, why might they not even be called occult qualities?” It is noteworthy that Newton himself stated in the preface to the *Principia* that “the moderns,” with whom he concurred, rejected “occult qualities.”²⁹ To be clear, Keill did not state that gravity is an occult quality, but that the cause of gravity is an occult quality. However, this point was easily and perhaps deliberately overlooked by critics of Newton's theory of universal gravitation. For instance, in his review of *Praelectiones chymicae* by the English physician John Freind (1675–1728) – a book to which we will refer again later – the German philosopher Christian Wolff (1679–1754) wrote that “Keill with his followers truly returns to occult qualities.”³⁰

Newton's terse statements in the comment to Definition 8 and the scholium to Section 11 in Book I could be interpreted differently by its readers. British authors generally viewed Newton's neutrality regarding the cause of gravity in a more positive way than their French and German counterparts. As is well known, Newton's refusal to treat the cause of forces was criticised immediately by Gottfried Wilhelm Leibniz (1646–1716), who described it as “not philosophical enough,” thus implying that the *Principia* was not really a work of physics or natural philosophy.³¹ Similarly, a review of the *Principia* in a French periodical complained that Newton had not considered his problems physically, but had done so “as a simple geometer.”³² There are some British authors who levelled such criticism at Newton, but these remained on the margins or outside of the public debate. Besides North and Greene, who we discussed above, the most outspoken case we have found is the Calvinist divine John Edwards (1637–1716), who argued along these lines in a book mostly concerned with

Keill's *De operationum chymicarum ratione mechanica*,” *Ambix*, 36 (1989), 135–152, and Peter R. Anstey, “Experimental Pedagogy and the Eclipse of Robert Boyle in England,” *Intellectual History Review*, 25 (2015), 115–131, at 118–120.

29 Keill, *Introductio*, 3: “Et si verè illarum causæ nos lateant, quidni etiam qualitates occultæ dici mereantur?”; Newton, *The Principia*, 381; idem, *Principia* (ed. 1687), unpaginated preface.

30 [Christian Wolff], Review of John Freind's *Praelectiones chymicae* ..., *Acta eruditorum*, [29] (1710), 412–416, at 412: “Verum enim vero Dn. Keilius cum sequacibus redit reapse ad qualitates occultas.”

31 Leibniz to Huygens, October 1690, in Christiaan Huygens, *Oeuvres complètes de Christiaan Huygens*, eds., David Bierens de Haan, Johannes Bosscha Jr., Diederik Johannes Korteweg, Albert Antonie Nijland and Johan Adriaan Volgraff, 23 vols. (The Hague, 1888–1950), IX, 524.

32 [anon.], Review of the *Philosophiae naturalis principia mathematica*, *Journal des sçavans*, [23] (1688), 153–154, at 153: “on ne peut regarder ces demonstrations que comme mecaniques. Puisque l'auteur reconnoit lui-mesme à la fin de la 4 page, & au commencement de la 5. qu'il n'a pas considéré leurs principes en Physicien, mais en simple Geometre.”

arguing against the Copernican system. Edwards believed that Newton's universal gravitation, which the former was otherwise happy to use as an argument against Descartes, could not count as proof for the Copernican system either, "for he [Newton] is oblig'd first to prove and demonstrate his supposed notion of *Gravity*, and the *Cause* of it."³³

Such reactions remained marginal in the British context. Although it is difficult to explain why exactly this was the case, it is useful to take a number of British developments into consideration. First of all, there were important natural philosophical precedents of causal neutrality. There are, for instance, striking parallels between Newton's position on the cause of gravity and that of John Wallis (1616–1703), the Savilian Professor of Geometry at Oxford and arguably one of Newton's closest compeers at the time of the publication of the *Principia*. In the beginning of his *Mechanica: sive, de motu, tractatus geometricus* (1670), a treatise dealing with motion geometrically, as did Newton's *Principia*, Wallis had proclaimed that "[w]hat, then, be the principle of gravity, in a physical consideration, we do not here investigate," adding that by the name of gravity he understood "a force of moving downwards."³⁴ Wallis thus explicitly refused to discuss the cause of gravity, since this was a physical rather than a mathematical matter and thus beyond his scope. A different precedent for causal neutrality can of course be found in Robert Boyle's philosophical work. Boyle (1627–1691), doubtlessly one of the main authorities in British natural philosophy at the time of the *Principia*'s appearance, discussed for example the "springiness" of the air without ascribing a cause to it.³⁵

Secondly, apart from these natural philosophical precedents, anti-Cartesian sentiments in all likelihood played a role in the British acceptance of Newton's causal neutrality. Descartes had endorsed a contact model of inter-particular interaction and set the quest for underlying direct-contact mechanisms as a standard for proper natural philosophical explanations of phenomena.³⁶ At the same time, Descartes had argued that such explanations should provide complete causal stories of the physical production of effects. As we will detail below, these arguments had already met with substantial criticism in Britain

33 John Edwards, *Brief Remarks upon Mr. Whiston's New Theory of the Earth* (London, 1697), 44.

34 John Wallis, *Mechanica: sive de motu, tractatus geometricus, pars prima* (London, 1670), 3–4: "Quodnam sit, in consideratione Physicâ, Gravitatis principium; non hic inquirimus [...] sufficit, ut Gravitatis nomine, eam intelligamus, quam sensu deprehendimus, Vim deorsum movendi."

35 Michael Hunter and Edward B. Davis, eds., *The Works of Robert Boyle*, 14 vols. (London, 1999–2000), vol. 3, 121.

36 Stephen Gaukroger, *Descartes' System of Natural Philosophy* (Cambridge, 2002), 113.

before 1687. Importantly, Newton's view on these issues was entirely different from those of Descartes. Newton was perfectly comfortable with identifying only the proximate cause, i.e., gravitational force, of heavenly and terrestrial motions while abstracting of their remote cause, i.e., the cause of gravitational force, as he stated in the comment to Definition 8.³⁷ Newton's step-by-step method that allocates the search of ultimate causes to a future phase in natural philosophical inquiry was likely appealing to British natural philosophers who endorsed the "inductive' gradualism"³⁸ of Francis Bacon (1561–1626), or the call by Robert Moray (1609–1673) to avoid any explications of natural phenomena that take recourse to "Original causes."³⁹

Thirdly, although the *Principia* remained silent about the cause of gravity, various British readers nevertheless regarded the *Principia* as having unravelled the causes of phenomena and explained these phenomena. Declarations to this effect were usually isolated statements and did not elaborate on the sense in which the *Principia* provided explanations. One such case is the second and enlarged edition of Samuel Clarke's annotated edition of Jacques Rohault's *Traité de physique*. As the new subtitle of this second edition of 1702 makes clear, most of the notes were "taken from the Philosophy of Isaac Newton the *Principia*."⁴⁰ Clarke argued that Newton gave the "true and adequate causes of all the celestial motions," but did not mention what these causes were at this point.⁴¹ Clarke did, however, elaborate on his own view of the matter later in the book, arguing that gravity was "a primitive and general law impressed on all matter by God."⁴²

37 Ducheyne, *The Main Business of Natural Philosophy*, 37–40.

38 Antonio Pérez-Ramos, "Francis Bacon and Man's Two-Faced Kingdom," in *Routledge History of Philosophy Volume IV: The Renaissance and Seventeenth-Century Rationalism*, ed. George H. R. Parkinson (London/ New York: 1993), 130–155, at 145, n. 13.

39 Quoted from Michael Hunter, *Science and the Shape of Orthodoxy. Intellectual Change in Late Seventeenth-Century Britain* (Woodbridge, 1995), 173.

40 Samuel Clarke, *Jacobi Rohaulti physica. Latine vertit, recensuit, & uberius jam adnotationibus ex illustrissimi Isaaci Newtoni Philosophia maximam partem haustis* (London, 1702), title page. This is, to our knowledge, the first publication in Britain that referred to Newton on its title page, apart from works by Newton himself. Other works referring to Newton in their title are Humphrey Ditton, *The General Laws of Nature and Motion; With their Application to Mechanics* (London, 1705), and Whiston, *Praelectiones physico-mathematicae*.

41 Clarke, *Physica* (ed. 1702), *Annotata*, 72: "verasque ac adaequatas omnium Motuum Coelestium causas, fere supra humanum ingenium patefecit." For statements similar to Clarke's, see [Locke], "Review," 436–437, [anon.], "Review of John Keill's *Introductio ad veram physicam*," in *The History of the Works of the Learned*, 8 (June) (1702), 377–380, at 378, and Whiston, *Praelectiones astronomicae*, 6.

42 Clarke, *Physica* (ed. 1702), *Annotata*, 82.

Variants of Clarke's view on the cause of gravity, which was based on Newton's refutation of Cartesian vortices, and particularly on his endorsement of a vacuum in Corollary 3 to Proposition 6, Book III of the *Principia*, were adopted by a number of authors, including Whiston and Cheyne. The first to argue along these lines was Richard Bentley (1662–1742), in 1693. By arguing that gravity was, in one way or another, divinely mediated and that no further mechanical cause could be found, proponents of this view aimed to refute the view that all natural phenomena could be explained by matter in motion. None of the people involved in this debate ascribed this view explicitly to Newton, and Newton himself never actually supported it. Nevertheless, this view implied that the *Principia* had explained gravity as far as could possibly be done from a natural philosophical perspective and thus certainly sat well with Newton's stance of causal neutrality.⁴³

The reading that the *Principia* was a mathematical work that abolished the search for the causes of phenomena altogether, closer to the precedent set by Wallis, was put forward by Gregory in 1692. Gregory did so on the occasion of his inaugural lecture as Savilian Professor of Astronomy at Oxford, where he became Wallis' direct colleague; before this Gregory had occupied a chair in mathematics in Edinburgh from 1683 to 1691.⁴⁴ One of the main themes of Gregory's inaugural lecture was the necessity of geometry to the advancement of astronomy, for which he praised in particular Kepler and a number of "English" scholars, among whom his predecessors in the Savilian Chair of Astronomy, Seth Ward (1617–1689) and Christopher Wren (1632–1723), as well as Wallis and, finally, after a brief intermezzo in which he rebuked Descartes, "the excellent geometer Mr Issac [sic] Newton," who had found "the measure of the centripetal force (tending to a given centre) of the body borne in that orbit, from whatever cause that force may arise, be it from a deeper mechanical one or from a law imposed by the supreme creator of all things."⁴⁵

43 Richard Bentley, *The Folly and Unreasonableness of Atheism* (London, 1693), Sermon 7, 8–9, 24–26, and 30–31, and Sermon 8, 32. Whiston and Cheyne, too, took this view, but did not mutually agree on how God mediated gravity. We discuss these matters at length in Ducheyne and Van Besouw, "Readers."

44 On Gregory, see Christina M. Eagles, "David Gregory and Newtonian Science," *British Journal for the History of Science*, 10 (1977), 216–225, and eadem, "The Mathematical Work of David Gregory, 1659–1708" (PhD dissertation, University of Edinburgh, 1977).

45 Gregory's lecture is printed both in the original Latin and translated into English in P. D. Lawrence and A. G. Molland, "David Gregory's Inaugural Lecture at Oxford," *Notes and Records of the Royal Society of London*, 25 (1970), 143–178; for the quote, see 169/162 [Latin]. Contrary to what one could expect, we have found only few references to "laws of nature," or laws as causes in public comments on the *Principia* prior to the second edition. Exceptions are [Locke], "Review," 436–437; [Cheyne], *New Theory*, in the separate *Essay*,

This remark about Newton's disregard for causes was the finale of Gregory's endeavour to contrast mathematical with causal approaches, which he started with a discussion of Kepler's approach. Gregory praised Kepler much for his mathematical work, but disagreed with his search the "archetypal causes, however beautiful," with which Kepler "seemed more to aspire to and desire a path to Olympus than to scale the heavens with the help of geometry."⁴⁶ Concerning Descartes, Gregory commented that it was

astonishing that after Kepler's bold and fruitful efforts to advance natural philosophy by the help of geometry, there should have appeared any philosopher and particularly a geometer, namely Descartes, who should leave this one narrow path and try to investigate the causes of things logically, or rather, sophistically.⁴⁷

In the same place, he later referred to Descartes' cosmology as "a fable."⁴⁸ What Gregory argued for was that the best philosophy, epitomised by Newton, was mathematical itself, and Gregory even went so far as to assert that "for the further improvement of natural philosophy a more advanced geometry must be found."⁴⁹ Gregory's *Astronomiae* (1702) again dismissed earlier philosophers, pointing out that Newton was able to handle the inequalities in the motions of the moons of other planets whereas, "before the most fortunate Newton, the astronomers hoped to solve [these motions] from hypotheses[,] or rather philosophers hoped to explain [these motions] from physical causes."⁵⁰ It seems that, for Gregory, assigning physical causes automatically involved speculation, since such causes are fundamentally hidden to us. In order to avoid speculation, the search for causes was to be abandoned entirely. It was Gregory's understanding that he had Newton on his side, given the latter's neutrality

24; [anon.], "Review of John Keill", 378; Samuel Clarke, *Jacobi Rohaulti physica. Latine vertit, recensuit, & Adnotationibus ex illustrissimi Isaaci Newtoni Philosophia maximam partem haustis* (London, 1710), 51. None of these elaborate on the matter.

46 Lawrence and Molland, "David Gregory's Inaugural Lecture," 167/161 [Latin].

47 Ibid. 168/162 [Latin].

48 Ibid. 171/164 [Latin]. Gregory here turned Descartes' own words against him. The term "fable" is used in various places throughout *Le Monde*, and refers to the book itself; see, e.g., *Le monde de Mr Descartes, ou, le traité de la lumiere* (Paris, 1664), 103, "n'ayant autre dessein que de vous raconter une fable."

49 Lawrence and Molland, "David Gregory's Inaugural Lecture," 172/165 [Latin].

50 David Gregory, *Astronomiae physicae & geometricae elementa* (Oxford, 1702), 282: "tendentia Secundarii motus maxime compositus redditur, iisque afficitur inaequalitatibus, quas Astronomi Hypothesibus salvare potius quam Philosophi ex Causis Physicis explicare, ante felicissimum Newtonum, sperabant."

regarding the cause of gravity, which explains why he considered Newton's approach in the *Principia* an exceptionally valuable one.

A variation on this attack on physical causes was launched simultaneously by Archibald Pitcairne, a close friend of Gregory. Pitcairne became professor of medicine at Edinburgh in 1685 and continued in that role until his death in 1713, with a short intermission in 1692–3, during which he held a chair in medicine at Leiden University. Although a lack of material evidence about Pitcairne's early views obstructs a thorough reconstruction, it seems plausible that Pitcairne's interest in combining his two fields of expertise – mathematics and medicine – had already been kindled by the so-called 'iatromechanists' Giovanni Borelli (1608–1679) and Lorenzo Bellini (1643–1704), to whom he would often refer.⁵¹ Pitcairne studied the *Principia* together with Gregory shortly after its publication.⁵² In March 1691/2, just before his inauguration at the University of Leiden, Pitcairne visited Newton in Cambridge, who entrusted him with his manuscript *De natura acidorum*.⁵³ In Leiden, Pitcairne delivered his inaugural dissertation, entitled *Oratio, quâ ostenditur medicinam ab omni philosophorum sectâ esse liberam* (*Oration in which it is shown that medicine is free from every sect of philosophers*) shortly afterwards, on 26 April 1692. Here he complained that contemporary medical sects attempted to uncover the "absolute natures and intimate causes of things," and were led by philosophers quarrelling about "physical causes." Such causes Pitcairne deemed "neither useful, nor necessary" in medical research.⁵⁴ He asserted that the search for causes had introduced conjecture, falsity and dispute into medicine,⁵⁵ and that physicians would do better to imitate the practices of astronomy, which remained free from sectarianism. Astronomers, Pitcairne asserted, refrained from mistaken opinions and fables and instead compared and brought together observations, allowing only for few postulates. Astronomers' demonstrations do not benefit from "substantial forms, a subtle matter, or from a fortuitous congression of bodies," he pointed out.⁵⁶

51 On Pitcairne's use of Borelli and Bellini, see, e.g., Guerrini, "Pitcairne," 72.

52 Eadem, "Tory Newtonians," 294.

53 Turnbull, *Correspondence*, vol. 3, 205–214.

54 Archibald Pitcairne, *Oratio, quâ ostenditur medicinam ab omni philosophorum sectâ esse liberam* (Leiden, 1692), 11: "rerum naturas absolutas caussasque intimas," 10–11: "Ex hisce deduco caussarum physicarum investigationem qualem instituere solent Philosophi Medicis neque utilem esse neque necessariam: hæ enim sunt de quibus sectarum patroni ferè ab orbe condito in hæc usque tempora nequicquam litigarunt."

55 Ibid., 14–15. A similar statement is made in Mead, *De imperio*, xxv.

56 Pitcairne, *Oratio*, 16: "Astronomicis quidquam praesidii in iis esse sentit quae hodie quoque inani disceptatione vexantur, neque in demonstrandis motuum caelestium

Although Pitcairne did not mention Newton's name in his oration, there can be little doubt that he was thinking about Gregory and Newton in these passages. From a dissertation Pitcairne presided in Leiden in 1693, it is evident that he considered the famous Cantabrigian someone who excelled in the search for the properties and forces of bodies. In this dissertation, it is stated that hopefully, "by the help of the principles that are exposed by this great man [i.e., Newton], the forces and properties of bodies serviceable to medical use and the relief of men can be discovered with more certainty and ease."⁵⁷ For Pitcairne, denouncing the search for causes and unravelling the properties and forces of bodies was characteristic of Newton's geometrical approach. Gregory and Pitcairne thus took an approach very different from that of Clarke: they seem to have had little interest in using Newton's natural philosophy to proselytize their religious views.⁵⁸

After having left Leiden for Edinburgh, Pitcairne delivered a lecture at the Royal College of Physicians of Edinburgh in 1694 on the cure of fevers. In this lecture, which was subsequently published in 1695, he defended his own medical approach, which was informed by mathematics and mechanics, against that of more empirically oriented and less theory-driven physicians.⁵⁹ Pitcairne's lecture and publication kicked off a bitter pamphlet war among Edinburgh physicians. Even though the relevant pamphlets mainly dealt with fever-related topics on which he had nothing to add, Newton was mentioned by a certain James Johnston in a pro-Pitcairne pamphlet for his supposedly anti-causal stance. This pamphlet claimed that Pitcairne had merely "demonstrated the manner how respiration is performed exactly according to nature" and had not been looking for further physical causes of respiration, since "Mr. *Newton* has taught us, that no man ever knew a Physical cause."⁶⁰

affectionibus & symptomatis ullum a formis substantialibus, materia subtili aut fortuito atomorum congressu emolumentum elicit."

57 Idem, *De motu*, C: "Et quandoquidem de Geometris sermo incidit, non possum non gratulari huic Sæculo & Arti Nostræ, quod Geometria in tantum fastigium sit evecta à plurimis quidem peritissimis artificibus, præcipuè tamen ab Isaaco Neutono, ut sperandum sit ope Principiorum quæ à magno illo Viro sunt ostensa, inventum iri certius faciliusque vires & proprietates corporum Medico usui & Hominum solatio inservituras."

58 It should be pointed out that Bentley, Whiston, and Clarke were all ordained priests of the Church of England. By contrast, Gregory, and certainly Pitcairne, seem to have been dismissive of organised religion; see Guerrini, "Tory Newtonians," and Alisdair Raffe, "Archibald Pitcairne and Scottish Heterodoxy," *The Historical Journal*, 60 (2017), 633–657.

59 Archibald Pitcairne, *Dissertatio de curatione februm quæ per evacuationes instituitur* (Edinburgh, 1695).

60 [James Johnston], *A Short Answer to a Late Pamphlet Against Doctor Pitcairn's Dissertations*. By J. J. M.D. (Edinburgh, 1702), 11; see David E. Shuttleton, "'My Own Crazy Carcase': The Life

In the same series of pamphlets, however, Cheyne, who was also on Pitcairne's side, argued for quite the opposite. Cheyne complained about physicians who either grounded their treatment in absurd theories, or were "rather *Empiricks* than *Physicians*" and "knew nothing either of the Cause of the Distemper, or of the Reason of the Cure." Instead, and like Pitcairne, Cheyne asserted that medicine should be more like astronomy, based on improving previous observations of the phenomena and thereafter "applying the Science of Quantity (*i.e.* Geometry and Numbers) to investigate their [*i.e.*, the phenomena's] Orbits, their Distances, the Laws of their Motions, their Natures, and their Causes." While so doing, Cheyne clearly referred to Newton as the exemplary astronomer.⁶¹ Cheyne thus indicated that Newton in fact dealt with the causes of the natural phenomena, although Cheyne did not elaborate in this particular publication on what that implied. Nevertheless, he agreed with Johnston that the *Principia* provided arguments against speculative approaches, although in doing so he did not refer specifically to Newton's neutrality with respect to the cause of gravity, as Johnston and others discussed in this section had.

4 Newton's Approach to Physical Inquiry in the *Principia* (III): Observations, Phenomena, and Experiments

As the example of Cheyne shows, another aspect that readers of the *Principia* singled out was its reliance on observations, phenomena, and experiments. As Newton stated in the preface to the *Principia*, he aimed to "reduce the phenomena of nature to mathematical laws" and, as any reader of Book III would have noticed, used astronomical observations to inform his account of the system of the world. References to Newton's use of observations and phenomena can be found in the inaugural orations of Gregory and Pitcairne, but are not widespread in the period we consider. Those who made such references, at least before the appearance of Newton's *Optice* in 1706, were almost

and Works of Dr George Cheyne (1672–1743)," (PhD dissertation, University of Edinburgh, 1992), 15ff. for the identification of the author, and an account of the pamphlet war.

- 61 [Cheyne], *New Theory*, in the separate *Essay*, 2–5; see 24–27 for references to Newton. It should be added that his main opponent in the pamphlet war, Charles Oliphant (1666–1719), a physician and brother-in-law of David Gregory, did not mention Newton. Oliphant seems mostly to have been concerned with defending the traditional education of physicians and opposing the reduction of medicine to the study of physiology, arguing that there were "a Million of other things more necessary to be known," and that while Borelli was a great mathematician, "none ever pretended to call him a Physician," see [Charles Oliphant], *A Refutation of the Short Answer to the Examination Dr. Pitcairne's Dissertation* (Edinburgh, 1702).

without exception academically linked to Gregory or Pitcairne.⁶² In some theses defended under Herbert Kennedy (d. 1698) at the University of Edinburgh in 1694, in which explicit homage is paid to his former colleague Gregory, there is an explicit juxtaposition between Descartes and Newton: "Descartes has given us a hypothesis, i.e. a fable, not a philosophy; Newton has revealed a philosophy, not a hypothesis,"⁶³ with the term "fable" appearing again. Kennedy's tribute to Newton contained a reference to the preface of the *Principia*, which was meant to underscore that Newton's natural philosophy was based on phenomena: "For the whole difficulty of philosophy turns around (as Newton teaches in the preface of his *Philosophical Principles*) that we should investigate the forces of nature from the phenomena of motion: and then that we demonstrate from these forces the other phenomena."⁶⁴ In 1704, the London physician Richard Mead (1673–1754), a former student of Pitcairne, likewise contrasted Descartes' conjectures and hypotheses to Newton's "higher principles that are consonant to things themselves [i.e., to phenomena]."⁶⁵

As is clear from the foregoing, Gregory, Pitcairne, and several of their students played an important role in the early discussion of Newton's methodology. There are various reasons why they were particularly well positioned to do so. First of all, it seems that Gregory, the astronomer, and Pitcairne, through his interest in Borelli and Bellini, had been using a combination of reliance on observations and mathematical language already before they knew of the *Principia*. Thus, they might have considered Newton as a natural ally, a figure to rally around. A second reason, no doubt, was Pitcairne's knowledge of *De natura acidorum*, a treatise that aimed to explain various chemical

62 See Lawrence and Molland, "David Gregory's Inaugural Lecture," 166/159–160 [Latin], and Pitcairne, *Oratio*, 15–16, in which natural philosophy not based on observations is called a "fable." See also [Cheyne], *New Theory*, in the separate *Essay*, 5 and 24.

63 Herbert Kennedy, *Theses hasce philosophicas A.P.D.O.M. septimo idus quintileis in auditorio publico inferiori, ex mandato Senatus Academici propugnandas. D.D.C.Q. Herbertus Kennedy praeses* (Edinburgh, 1694), thesis 1: "Hypothesin, i.e. Fabulam, non Philosophiam dedit Cartesius: Philosophiam, non Hypothesin exhibuit Neutonus," thesis VI: "Philosophus D Gregorius M. D. & Mathesos Professor, olim Noster, nunc Oxoniensis." For discussion, see Christine M. Shepherd, "Newtonianism in Scottish Universities in the Seventeenth Century," in *The Origins and Nature of the Scottish Enlightenment*, eds. R. H. Campbell and Andrew S. Skinner (Edinburgh, 1982), 65–85, at 72–73.

64 Kennedy, *Theses*, thesis 1: "Omnis enim Philosophiae difficultas in eo versatur (docente Neutono in praefatione libri de Principp. Philosophiae) ut a Phaenomenis motuum investigemus vires naturae: Deinde ab his viribus demonstramus Phaenomena reliqua." The same quote was also used, for the same purpose, in [Johnston], *Short Answer*, 36–37.

65 Mead, *De imperio*, xxv, 6–7.

phenomena, which were certainly observed through careful experimentation, in terms of attractive forces.

Thirdly, since Pitcairne and his medical students explained much of the working of bodies in terms of fluid flows, they had a strong interest in hydrostatic phenomena. These interest led them not only to authorities in mathematized physiology, such as Borelli and Bellini, but also to the hydrostatical work done in Book II of the *Principia*, in which Newton relied on a combination of advanced geometry and general observation of the phenomena.⁶⁶ The various but imprecise references to Newton in Pitcairne's lectures can, with some work, be traced back to Pitcairne's knowledge of *De natura acidorum*, for the attraction between different fluids, and of Book II, for his discussion of the discharge of liquids.⁶⁷ Cheyne, who argued in his *A New Theory of Contin'd Fevers* that fevers could be explained by obstruction of the fluid flows in the body, seems to have had knowledge of *De natura acidorum*, too, and referred more directly to Book II of the *Principia*. We find references to the scholium to Proposition 35 of Book II, which deals with the resistance conical bodies encounter in a resisting medium and to the scholium to Lemma II in Book II, which deals with surface resistance on circular bodies.⁶⁸ Clearly, Cheyne and Pitcairne were aware of the close attention paid to the phenomena in Newton's work.

Still, initial readers did not make a connection between Newton's *Principia* and experimental work, not even Pitcairne, Gregory, or their students. In fact,

66 On Book II of the *Principia*, see Smith, "Newtonian Style." The curriculum of most Scottish universities seems to have covered the mixed mathematical sciences such as optics and hydrostatics relatively well and various professors included some of Newton's findings on the matter in their courses; see Eagles, "David Gregory and Newtonian Science," and Shepherd, "Newtonianism."

67 Pitcairne, *De curatione*, 7: "veteres negotium hoc variâ attractione transigi volebant, quorum sententiam aptius illustrare, quàm ipsi poterant, facile illi fuerit, qui *Neutoniana* intelligit"; Pitcairne, *Dissertationes medicae*, 80: "vires diaphragmatis & musculorum abdominis tantas esse, ut officio onerique a nobis imposito pares esse facile possint. Viris illae sive investigentur ope *propositionis* 121 &c. primae partis operis Borelliani, sive auxilio principii Neutoniani ex Borellianis etiam eliciendi, prodibunt sane ingentes." This passage does not appear in an earlier version of this dissertation, which states that the dissertation was defended by one Hubertus Decker under the auspices of Pitcairne; this edition was published in 1693 in Leiden with Elsevier.

68 [Cheyne], *New Theory*, 42, 97; compare Newton, *Principia* (ed. 1687), 326–327, 253–254. The separately numbered *Essay* to [Cheyne], *New Theory*, which we have cited above, only appeared in the second print run of the Book. Robert E. Schofield, *Mechanism and Materialism: British Natural Philosophy in an Age of Reason* (Princeton, NJ, 1970), 49–50, 57–59, and Guerrini, *Obesity*, 56–59, are the most informative accounts of the works by Pitcairne and Cheyne to which we refer here.

as late as 1702, John Keill explicitly denied that Newton was to be considered an experimental philosopher. In the opening chapter on the “method of philosophising” of his *Introductio ad veram physicam*, Keill discussed four classes of philosophers with specific methods that, although they all had some benefits, had generally failed to improve physics: the “Pythagoreans or Platonists,” the “Peripatetic School,” “the followers of the experimental method,” and, finally, the mechanical philosophers, i.e., the “Cartesians.” Keill stated that he agreed with none of these sects and would only take parts of theirs to compose his own method of philosophising.⁶⁹ His own method, instead, complied with that of the “writers of the mathematical philosophy.”⁷⁰ Keill had identified a number of these mathematical philosophers before, with a list ranging from Archimedes to Galileo and Huygens, and finishing with Newton and Gregory, Keill's own mentor.⁷¹ He discussed this group particularly after criticising the Cartesians, whom he condemned for “ignoring geometry” and “daring to give the causes of natural things.”⁷² The “experimental philosophers,” a group of which Keill did not name its members, were chastised for jumping to conclusions when experiments seemed to support their “hypotheses.”⁷³ Though Keill argued experiments were necessary,⁷⁴ he thus explicitly included Newton in the group of illustrious philosophers who approached nature mathematically and abstained from causal speculation, and not with the experimental approach that did not.

There can be no doubt that, up to the mid-1700s, characterisations of Newton's approach in the *Principia*, although they abounded, were rather underdeveloped and sketchy. More help was on the way for those who wished to make sense of it, however. In 1706, an intervention by Newton himself affected the image of his thinking and the *Principia* that was being shaped by his contemporaries when he incorporated a number of methodological statements in the *quaestiones* to Clarke's Latin rendition of his *Opticks* (1704), the

69 Keill, *Introductio*, 1–2, see in particular: “Ex variis hisce philosophandi methodis, uti nulla est in qua omnia placent, ita in omnibus quaedam probare possumus; quocirca ut delectus habeatur oportet, ea eligendo quae usui maxime futura sunt, & rationem ex hisce omnibus compositam sequendo.” The mechanical philosophers are identified with the Cartesians by Keill in various places, see e.g. p. 7.

70 Ibid., 7: “philosophiae Mathematicae scriptores.”

71 Ibid., [v–vii].

72 Ibid., [v]: “Omnium errorum fons exinde permanasse videtur, quod homines Geometriae ignari philosophari ausi sunt & rerum naturalium causas reddere.”

73 Ibid., 6: “non nisi a theorista aliquo ad suam probandam hypothesim adducuntur; novimus enim hoc hominum genus ..., quam facile vel alios decipiant, vel seipsos in experimentis perficiendis decipi patiantur.” It is not clear to us whom Keill had in mind here.

74 See for example his praise for “egregiis nobilis Boylei experimentis”, Keill, *Introductio*, [vi].

Optice (1706). The *Optice* was more than just a translation into Latin of the *Opticks*, for it contained fifty pages of additional material in its *quaestiones*. In the last *quaestio* to the *Optice*, Newton reiterated and expanded upon the final paragraph of his comment to Definition 8 of the *Principia*, emphasising again that with the word ‘attraction’ he referred to the force “by which bodies tend toward each other” – “to whatever cause,” he wrote, “this force may be ascribed in the end.” For, as he continued, first from phenomena it should be determined “which bodies attract one another” and “which are the laws and properties of this attraction.” Then the “efficient cause of the attraction” is to be unravelled.⁷⁵ He furthermore criticised the “Cartesians,” on account of their view that the vortices would halt the celestial motions “by their tenacity and viscosity.”⁷⁶ Newton also stated that he considered the active principles producing gravity, fermentation and cohesion “not as occult qualities, from which the specific forms of things are supposed to originate, but as the universal laws of nature from which the things themselves are formed.” “Because,” he continued, “indeed the phenomena of nature show that these principles really exist, although their causes are not yet explained.”⁷⁷

From the draft material prepared for the 1706 *Optice*, it is clear that Newton’s discussion of active principles served the purpose of showing that matter is passive and cannot move itself.⁷⁸ It is highly probable that Newton did so not

75 Isaac Newton, *Optice: sive de reflectionibus, refractionibus, inflexionibus, & coloribus lucis libri tres*, trans. Samuel Clarke (London, 1706), 322: “Hanc vocem *Attractionis* ita hic accipi velim, ut in universum solummodo vim aliquam significare intelligatur, qua Corpora ad se mutuo tendant; cuicumq; demum causæ attribuenda sit illa vis. Nam ex phænomenis Naturæ illud nos prius edoctos oportet, quænam corpora se invicem Attrahant, & quænam sint Leges & Proprietates istius Attractionis; quam in id inquirere par sit, quanam efficiente causa peragatur Attractio.” This passage is quoted *in extenso* in Clarke, *Physica* (ed. 1710), 50–51, note 6.

76 Newton, *Optice*, 342: “Ex quo facile intelligi potest, si plures *Vortices* ex liquefacta Pice inter se essent contigui; tantaq; hi amplitudine, quanta *Cartesiani* illi; fore tamen, ut & ipsi & partes suæ omnes, propter tenecitatem suam & lentorem, Motum suum cito secum invicem communicarent, donec inter se omnes plane quiescerent.” This is one of the few, if not the only, public places in which Newton explicitly referred to the “Cartesians.” This reference was dropped from all later editions of the *Optice* and *Opticks*. On the differences between the various editions, see Steffen Ducheyne, “Newton on Action at a Distance,” *Journal of the History of Philosophy*, 52 (2014), 675–702.

77 Newton, *Optice*, 344–345: “considero, non ut *occultas Qualitates*, quæ ex *Specificis* rerum *Formis* oriri fingantur; sed ut *universales* Naturæ *Leges*, quibus res ipsæ sunt formatæ. Nam *Principia* quidem talia revera existere, ostendunt Phænomena Naturæ; licet ipso- rum Causæ quæ sint, nondum fuerit explicatum.” Again, this passage is quoted *in extenso* in Clarke, *Physica* (ed. 1710), 51, note 6.

78 These preparatory manuscripts are to be found (in chronological order) in Cambridge University Library, Special Collections, Add. Ms. 3970, fol. 620v, fol. 619r–v, fol. 252v, fol.

only to rebut foreign critics such as Leibniz, but more precisely to refute John Toland's (1670–1722) materialist reading of the *Principia* in the *Letters to Serena* (1704), according to which, motion is essential to matter and matter can move itself.⁷⁹ Newton must have been highly concerned with his religious reputation when preparing the 1706 *Optice* since, shortly after he was knighted by Queen Anne on 16 April 1705, a “hundred or more” protesting Cambridge students accused him of “Occasional Conformity” during the election that determined whether or not he would represent Cambridge University in parliament. The charge of these students was that Newton conformed to the teachings of the Church of England only outwardly but not privately.⁸⁰

In the *Optice*, Newton also characterised a twofold method to be used in natural philosophy. First, Newton stated, came the method of analysis, according to which causes are to be inferred from their effects (for instance, forces from motions). Afterwards comes the method of synthesis, according to which the discovered causes should be taken as principles and used to explain other phenomena proceeding from them, while also proving these explanations.⁸¹ Thus, Newton came to emphasise his reliance on empirical work. A number of publications appearing between the *Optice* and the second edition of the *Principia* made use of such statements and began to associate Newton more closely with methods relying on experimentation. Francis Hauksbee (1660–1713), the curator of experiments at the Royal Society, of which Newton had

254r, fol. 255r and fol. 256r. For arguments supporting this chronological order, see Frederik Dhondt and Steffen Ducheyne, “Appendix to Frederik Dhondt and Steffen Ducheyne, Theological and Religious Statements in Isaac Newton's Queries/Quaestiones to the Opticks/Optice,” DOI: 10.5281/zenodo.4543563, <<https://zenodo.org/record/4543563#.YTW5qJozZPY>>, accessed 10 September 2021.

79 John Toland, *Letters to Serena* (London, 1704), 165, 200–202. For further discussion, see Frederik Dhondt and Steffen Ducheyne, “Theological and Religious Statements in Isaac Newton's Queries/Quaestiones to the Opticks/Optice,” *European Journal of Science and Theology*, 17 (2021), 1–10, and Ducheyne and Van Besouw, “Readers,” 387–388.

80 William Cobbett, *The Parliamentary History of England from the Earliest Period to the Year 1803*, 36 vols. (London, 1806–20), vol. 6, at 496. For a discussion, see Richard S. Westfall, *Never at Rest: A Biography of Isaac Newton* (Cambridge, 1980), 623–626. Newton lost the election.

81 Newton, *Optice*, 347: “Quemadmodum in Mathematica, ita etiam in Physica, investigatio rerum difficilium ea Methodo, quæ vocatur *Analytica*, semper antecedere debet eam quæ appellatur *Synthetica*. Methodus *Analytica* est, experimenta capere, phænomena observare; indeq; ex rebus compositis, ratiocinatione colligere simplices; ex Motibus, vires moventes; & in universum, ex effectis, causas; ex causisq; particularibus, generales; donec ad generalissimas tandem sit deventum. Methodus *Synthetica* est, causas investigatas & comprobatas assumere pro Principiis, eorumq; ope explicare Phænomena ex iisdem orta, istasq; explicationes comprobare.” See Shapiro, “Experimental Philosophy,” for a discussion of Newton's method of analysis and synthesis.

become president in 1703, stated that Newton had made his discoveries by a “Method” of “Demonstrations founded on Experiments and Observations.” According to Hauksbee, Newton shared this method in particular with Boyle.⁸² Around the same time, Whiston asserted that the subtle matter of Descartes had been exploded “by Newton’s experiment and demonstration,” referring to experiments with pendulums measuring air resistance in the *Principia*.⁸³

In a critical review of Freind’s *Praelectiones chymicae* in the *Acta eruditorum*, the German philosopher Wolff pointed out that Freind, like Keill, promoted the principle of attraction, which Wolff considered as an occult cause and a return to “a certain fantastical scholastic philosophy or, even, to an enthusiastic philosophy like the one of [Robert] Fludd.”⁸⁴ Leibniz raised the same criticism against Newton in a letter to the Dutch scholar Nicolaas Hartsoeker (1656–1715), published in the *Journal de Trévoux* in 1712, after having earlier rejected action at a distance in his *Essais de théodicée* (1710).⁸⁵ In response to such criticism, Freind stated that his use of short-range attractive forces in his book was based on the “principles and the same method of arguing which Newton, the prince of mathematicians has introduced in philosophy.”⁸⁶ Freind, who had held an unpaid professorship at Oxford University in 1704 and shared important interests with his former colleague Keill, counterattacked Wolff. Freind wrote that the “Cartesians” “want to call themselves the masters of the mechanical philosophy,” but base their philosophy on the hypothesis of a vortex mechanics “that exists nowhere except in the thoughts of those who phantasize.”⁸⁷ In stark contrast, Freind wrote, Newton “feigns nothing and assumes nothing in his

82 Francis Hauksbee, *Physico-Mechanical Experiments On Various Subjects* [...] (London, 1709), [a2].

83 Whiston, *Praelectiones physico-mathematicae*, 265. We will refer again to this experiment below.

84 [Wolff], “Review,” 412. In his review, Wolff is referring to Keill, “Joannis Keill,” esp. 99–100. The difference between Keill’s and Freind’s proposals on the matter need not detain us here. For a discussion, see Schofield, *Mechanism*, 41–46. For an informative analysis of Wolff’s criticism of attractive forces, see Marius Stan, “Newton’s Concepts of Force among the Leibnizians,” in *Reading Newton in Early Modern Europe*, eds. Elizabethanne Boran and Mordechai Feingold (Leiden, 2017), 244–289, at 272–286.

85 Gottfried Wilhelm Leibniz, “Lettre de monsieur de Leibnits à monsieur Hartsoeker,” *Mémoires pour l’histoire des sciences & des beaux arts*, 12 (1712), 496–510, at 500, 503–504; and idem, *Essais de théodicée sur la bonté de dieu, la liberté de l’homme, et l’origine du mal* (Amsterdam, 1710), 27.

86 Freind, “Praelationum,” 331: “principia, ipsamq; argumentandi Methodum, quam Mathematicorum Princeps in Philosophiam intulit Newtonus.”

87 Ibid., 331: “Cartesiani [...] qui se magistros Philosophiae Mechanicae dici volunt, rationem hanc perpetuò tenuerunt, ut Hypothesin aliquam sumerent seu figmentum, quod nullibi nisi neque cogitatione fingentium existit.” Cf. *ibid.*, 340.

judgement, only that which is known by experiment and observation." Furthermore, "from his most certain principles he draws conclusions with mathematical precision that he then most fruitfully applies to other phenomena of nature that need to be explained" – an implicit reference to the method of synthesis discussed by Newton in the *Optice*.⁸⁸ In his response to Wolff, Freind furthermore defended Newton's theory of universal gravitation by showing that the method by which he arrived at this theory differs in important respects from the method of hypothesis followed by the "Cartesians." In doing so, Freind provided what was so far the most elaborate account of Newton's approach to natural philosophical inquiry in the *Principia*, whilst drawing on the new methodological material in Newton's *quaestiones* to the *Optice*.

5 Newton's Approach Exemplified by his Rejection of Descartes' Celestial Vortices

As we have seen, all features of Newton's approach discussed here were regularly perceived as contrasting with Descartes' method. We have seen Gregory assert that Descartes' cosmology was a fable because it did not use mathematics, as Newton's cosmology did. Kennedy used the same derogatory term, 'fable,' in particular to rebuke Descartes for using hypotheses, by contrast with Newton. Mead levelled similar criticism at Descartes. Whiston was particularly clear that it had been mathematical demonstrations and experiments with which Newton had destroyed Descartes' vortices, while Freind contrasted the hypothetical nature of Descartes' account with Newton's use of experiment. Clearly, contrasts between Newton and Descartes were frequently referenced in discussions of celestial vortices. In the scholium to Proposition 53, Book II, Newton had indeed concluded that "the hypothesis of vortices utterly conflicts with astronomical phenomena and is not so much conducive to explain the celestial motions as to confuse them."⁸⁹ This statement was immediately

88 Ibid., "Praelectionum," 331–332: "Nihil ille fingit, nihil pro arbitrio suo assumit; id solum quod Experimento & Observatione notatum [...]. Ex his principiis certissimas Mathematicâ ἀκριβέτης elicit conclusiones, quas deinde ad alia Naturæ Phænomena explicanda felicissimè accommodat." For another reference to Newton's use of experiments, see James Keill, *An Account of Animal Secretion, The Quantity of Blood in the Humane Body, And Muscular Motion* (London, 1708), 9, 15. This text by James Keill (1673–1719), John's brother, makes references to both the *Opticks* and the *Principia*.

89 Newton, *Principia* (ed. 1687), 400: "Hypothesis Vorticum cum Phænomenis Astronomicis omninò pugnat, & non tam ad explicandos quàm ad perturbandos motus cœlestes conducit."

picked up and frequently used to argue that Descartes' vortices had been delivered its *coup de grâce*.⁹⁰

A particularly strong repudiation of vortices can be found in Keill's *Examination of Dr. Burnet's Theory of the Earth* (1698), which was a particularly spiteful answer to Thomas Burnet's (ca. 1635–1715) infamous *Telluris theoria sacra* (1681), as well as – in less unfavourable terms – to Whiston's *A New Theory of the Earth, from its Original, to the Consummation of all Things* (1696). The antagonistic nature of Keill's *Examination* can be gathered from its opening sentence which states “[w]hat *Plutarch* particularly proves of the *Stoicks*, that they spoke more improbabilities than the Poets, may be extended to a great part of Philosophers, who have maintained opinions more absurd than can be found in any of the most Fabulous Poets, or Romantick Writers.”⁹¹ About Descartes, Keill underscored that the Frenchman was “so far from applying Geometry and observations to natural Philosophy, that his whole System is but one continued blunder upon the account of his negligence in that point.” In addition, he urged that “the Theory of the *Vortices*” cannot be rendered consistent with astronomical observation, as “the most Ingenious and Incomparable Mr. *Newton*” has shown “by his great and deep skill in Geometry.” According to Keill, Newton showed that it is impossible that the planets move in a vortex,

[s]o that the notion of a *Vortex* being ruined, the whole *Cartesian* system must of necessity fall to the ground; and that world, whose origination he [i.e., Descartes] pretended to have deduced from Mechanical principles, must be a wild chimera of his own imagination.⁹²

90 See [Halley], “Review,” 295; [Locke], “Review,” 442–443; Lawrence and Molland, “David Gregory’s Inaugural Lecture,” 171/164 [Latin]; Keill, *Examination*, 16; John Locke, *Mr. Locke’s Reply to the Right Reverend the Lord Bishop of Worcester’s Answer to his Second Letter* (London, 1699), 384; Clarke, *Physica* (ed. 1702), *Annotata*, 70; Gregory, *Astronomiae*, 99; Joseph Raphson, *A Mathematical Dictionary: Or, a Compendious Explication of All Mathematical Terms, Abridg’d from Monsieur Ozanam, and Others* (London, 1702), s.v. “vortex,” 99; Harris, *Lexicon*, s.v. “vortex”; Clarke, *Physica* (ed. 1710), 311; and Whiston, *Prælectiones physico-mathematicæ*, 273. Gregory, Harris, and Whiston referred explicitly to Proposition 53, Book II, and Whiston more generally argued against Descartes’ subtle ether by drawing on to the pendulum experiment reported by Newton in the General Scholium to Section 6, Book II (Newton, *The Principia*, 722–723).

91 Keill, *Examination*, 1.

92 Ibid., 16–17. See also John Witty, *An Essay Towards a Vindication of the Vulgar Exposition of the Mosaic History of the Creation of the World* (London, 1705), 59, which speaks about the “Vortices” of the “Cartesians,” which “the great Mr. *Newton* has demonstrated to be *Chimera*’s.”

As we have pointed out above, Newton's refutation of celestial vortices, as well as of the plenum, was also mobilised in religious contexts with the aim to show that not all phenomena are produced by mechanical causes and thus to leave room for divine intervention in the natural world. It should be pointed out that such criticism was not *per se* new. British resistance to Cartesian physics, often fuelled by religious motivations, in particular by opposition to the materialism associated with Thomas Hobbes (1588–1679), has been documented for earlier periods as well. Isaac Barrow (1630–1677), Newton's mentor, was among its important opponents.⁹³ As Sarah Hutton has pointed out, the English reception of Descartes' philosophy as a whole was rather critical.⁹⁴ Catherine Wilson has recently shown that, already before the *Principia*, certain British writers were convinced that Descartes' ontological arguments supporting the existence of God, his dualism, and his method of doubt had a detrimental effect on religion.⁹⁵ Henry More (1614–1687) argued that because of his *res extensa* Descartes could not allow the presence of immaterial beings, including God, in the physical world.⁹⁶ Ralph Cudworth (1617–1688) similarly called Descartes "an *Hypocritical Theist*, or a *Personated and Disguised Atheist*."⁹⁷ The *Principia*'s refutation of vortices must certainly have played a role in making the work more appealing to those who held such

93 Mordechai Feingold, "Isaac Barrow: Divine, Scholar, Mathematician," in *Before Newton: The Life and Times of Isaac Barrow*, ed. idem (Cambridge, 1990), 1–104, at 25–29; see also idem, "Experimental Philosophy: Invention and Rebirth of a Seventeenth-Century Concept," *Early Science and Medicine*, 21 (2016), 1–28, at 6–7 for opposition to Descartes by William Petty and Samuel Hartlib; see Douglas Jesseph, "Mechanism, Skepticism, and Witchcraft: More and Glanvill on the Failures of the Cartesian Philosophy," in *Receptions of Descartes: Cartesianism and Anti-Cartesianism in Early Modern Europe*, ed. Tad M. Schmaltz (London, 2005), 199–217, on More and Glanvill; and Alisdair Raffie, "Intellectual Change before the Enlightenment: Scotland, the Netherlands and the Reception of Cartesian Thought, 1650–1700," *The Scottish Historical Review*, 94 (2015), 24–47, at 34–41 for resistance to Descartes in Scotland.

94 Sarah Hutton, "Cartesianism in Britain," in *The Oxford Handbook of Descartes and Cartesianism*, eds. Stephen Nadler, Tad M. Schmaltz and Delphine Antoine-Mahut (Oxford, 2019), 496–514, at 497.

95 Catherine Wilson, "What (Else) Was Behind the Newtonian Rejection of Hypotheses?" in *Experiment, Speculation and Religion in Early Modern Philosophy*, eds. Alberto Vanzo and Peter R. Anstey (New York, 2019), 158–183, at 160–161, 167–171, 173.

96 See Henry More, *Enchiridion metaphysicum: Sive, de rebus incorporeis* (London, 1671), 358, where he refers to Descartes as a "nullibist." For a discussion, see David Leech, "Henry More and Descartes," in *Plotinus' Legacy. The Transformation of Platonism from the Renaissance to the Modern Era*, ed. Stephen Gersh (Cambridge, 2019), 127–145, at 135–140.

97 Ralph Cudworth, *The True Intellectual System of the Universe: The First Part; wherein, All the Reason and Philosophy of Atheism is Confuted; and its Impossibility Demonstrated* (London, 1678), 646. For a discussion, see Hutton, "Cartesianism," 506–509.

pre-existing anti-Cartesian sentiments, thereby helping to spread Newton's fame and in return creating new targets and audiences for those who argued against Descartes.

6 Conclusion: Cotes' Synthesis, or Breaking with the Past

In the previous sections, we have seen how readers identified a quite stable set of salient features of Newton's approach, and how the *Principia* was read in various diverging ways. Although many readers emphasised its mathematical nature, they did so in different ways. Some readers, such as Locke, believed that the use of mathematical demonstrations gave the *Principia* a certainty that other works in natural philosophy did not have. Many readers, such as Halley and Cheyne, praised Newton for his exceptional mathematical skills in quite hyperbolic terms, and Cheyne also connected Newton's mathematical orientation in natural philosophy to intelligibility. Pitcairne was the only one to assert that the aim of Newton's mathematical approach was to discover the forces and properties of bodies.

Newton's neutrality regarding the cause of gravity, expressed in the comments to Definition 8 and the scholium to Section 11, Book I, was readily picked up, but British readers of the first edition of the *Principia* developed two different interpretations of those comments. On the one hand, Locke, Cheyne, Clarke, and several others, took the definition to entail that Newton did not ascribe a cause to gravity, but that the forces he discovered are nonetheless causes of motion. On the other hand, Pitcairne and Gregory, as well as several of their students but not Cheyne, saw it as an indication that Newton discarded causes from natural philosophical investigation altogether. Pitcairne and Gregory considered Newton's approach antithetical to approaches based on hypotheses because of its neutrality with respect to the cause of gravitation.

Newton's approach was not only characterised as mathematically oriented, it was also portrayed as being rigorously based on phenomena, observations, and experiments. Such was asserted by Pitcairne and Gregory, Kennedy, Cheyne, Johnston, Mead, and Freind. Of those who stressed this point, Hauksbee was the only one not directly connected to Pitcairne and Gregory, who emerge from our survey as the pivotal players in early discussions about Newton's methodology. Seen in this light, the attempt by John Keill, Gregory's student, to distance Newton from experimental approaches is something of an anomaly. That experiments became a defining characteristic of Newton's method quite late in the period under consideration might be connected to a relative lack of interest in Newton's study of fluid resistance in Book II, which

contained several experiments, as well as to the fact that the importance of experiments was not explicitly defended in first edition of the *Principia*. With the publication of the *Opticks*, which contains an abundance of experiments, and especially the *Optice* in 1706, in which it was stated that the starting point of the method of analysis consisted in “performing experiments and observing phenomena,” readers started to consider Newton’s work increasingly in experimental terms.⁹⁸ Yet with the partial exception of Hauksbee in 1709, we have not been able to find any text prior to Cotes’ editorial introduction that describes Newton as a proponent of the “experimental philosophy,” let alone mentions Newton as its leader.⁹⁹

That the *Principia* torpedoed celestial vortices became an important feature of its reputation, and many readers portrayed Newton as someone who dispelled hypotheses, in contrast to Descartes. There were also polemical uses of Newton, however, in which Descartes was not the main target. For example, Pitcairne used Newton’s geometrical method in order to reorient medicine away from essences and “intimate causes.” Protégés of Pitcairne referred to Newton in the Edinburgh pamphlet war, using Newton to dress down their opponents as either mere empirics or physicians who overly and unnecessarily concentrated on physical causes. Newton’s approach was also used in several polemics wherein Descartes was but one of the targets. Gregory had contrasted Newton’s causal neutrality not only with Descartes, but also with Kepler, while Freind targeted both Descartes and Wolff. Of interest also is John Keill’s rebuke of Whiston, where Whiston himself openly claimed to have built his cosmographical work on the *Principia*.

As can be gathered from our survey, the most detailed accounts of Newton’s natural philosophical approach were given in polemic contexts.¹⁰⁰ These polemics have generally been interpreted as opposing Newton or “Newtonianism” to particular adversaries. A closer look at the exact terms of these polemics, however, creates space for a rather different story. In the Edinburgh pamphlet wars, for example, Newton was mentioned several times and this certainly

98 Newton, *Optice*, 347: “Methodus *Analytica* est, experimenta capere, phaenomena observare.” As pointed out in Shapiro, “Experimental Philosophy,” Newton first publicly introduced the term “experimental philosophy” in the second edition of the *Principia*.

99 That Newton was perceived as such has been suggested most forcefully in Anstey, “Experimental Pedagogy.” Although we do not necessarily disagree with Anstey’s argument that a general shift took place from Boyle to Newton as the perceived exemplar of British “experimental philosophy,” we conclude from our survey that this shift did not take place before the 1710s.

100 This also applied to a significant degree to Newton’s own explications of his method; see Shapiro, “Experimental Philosophy,” passim.

indicates that his work was well known and widely appreciated by the early years of the eighteenth century. However, the actual oppositions were cast, by Pitcairne and his students, in terms of an approach to medicine based on a simple theoretical framework and critical observation versus approaches to medicine based either on speculations or on plain non-theoretical empiricism as embodied by Hippocrates. When Keill criticised the 'Cartesians', he did not oppose their approach to a method that he considered to be unique to Newton. Rather, he contrasted their approach to that of the mathematicians in general. Newton was, of course, a prime example of the mathematical approach, but nothing indicates that Keill thought of Newton as the trendsetter or originator of that approach. Although perceptions of Newton's mathematically and observationally based approach in the *Principia* were certainly used as an exemplar of proper conduct, there is no indication that the authors discussed here, with the partial exception of Freind in 1711 and the poet Blackmore in 1712, conceived of 'Newtonian' and 'non-Newtonian' approaches, let alone that they wished to present themselves as disciples of one or the other.

In the introduction to this paper, we have asserted that Roger Cotes' editorial preface to the second edition was, in a particular way, a historical first in setting apart Newton's approach in the *Principia*. Clearly, we do not mean to say that Cotes' was the first to argue that the *Principia* made use of sophisticated mathematical techniques, that it used experiment, avoided hypotheses, or showed that Descartes was wrong; as we have detailed, all these points had been made before. Nevertheless, we argue that Cotes' introduction did much more than provide an accessible overview of the arguments leading up to the theory of universal gravitation, explaining that celestial motions cannot be accounted for by vortices, and attempting to neutralise the objection that gravity is an occult quality.¹⁰¹ Cotes, in contrast to Keill and others, presented Newton's natural philosophy as a clear and definitive break with the past and as a serious competitor to the existing natural philosophies of the Scholastics and Cartesians. He did so in a way for which there was, in our view, very little precedent.

Let us provide some details. Cotes observed that the Scholastic philosophers, who derive their approach "from Aristotle and the Peripatetics," had endowed "the individual species of things with specific occult qualities," on which "the operations of individual bodies depend in some unknown way." Since they were "wholly concerned with the names of things rather than with the things themselves," they must be regarded as inventors of "philosophical

101 Newton, *The Principia*, 385–399; idem, *Principia* (ed. 1713), *Editoris praefatio*, b2–d^v.

jargon, rather than teachers of philosophy.”¹⁰² Those who, following Descartes, Cotes continued, “take the foundation of their speculations from hypotheses, even if they then proceed most rigorously according to mechanical laws, are merely putting together a romance [Fabulam], elegant perhaps and charming, but nevertheless a romance [Fabulam].” The natural philosophy of those who endorse “the Newtonian philosophy,” on the other hand, was according to Cotes based on experiment, and, accordingly, its proponents “assume nothing as a principle that has not yet been thoroughly proved from phenomena.” These philosophers followed a twofold method, Cotes pointed out: “From certain selected phenomena they deduce by analysis the forces of nature and the simpler laws of those forces, from which they then give the constitution of the rest of the phenomena by synthesis.” “This is,” Cotes remarked, “that incomparably best way of philosophizing [Philosophandi ratio] which our most celebrated author [i.e., Newton] thought should be justly embraced in preference to all others.”¹⁰³

We conclude from our study that the only British author who publicly made similar statements before 1713 is Freind, who did so in his reaction to Wolff which appeared near the end of the period considered here, in 1711. Armed with knowledge of Newton's methodological statements in the *quaestiones* to the *Optice*, Freind opposed the approach of the “Cartesians” to a “method of arguing” he considered specific to Newton, namely a method according to which one should “feign nothing,” assume only what is known through experiments and observations, and apply the joint method of analysis and synthesis. We thus find that this relatively little-known text gave the first explicit characterisation of a method unique to Newton.

That other readers did not regard Newton's approach as unique or breaking fundamentally with the past, is suggested by the fact that they often named Newton as one among other exemplary thinkers. This happened right from the beginning, when Halley announced the *Principia* as being in line with the works of Galileo, Torricelli, and Huygens. Given that Halley's articles were directly aimed at propagating the *Principia*, one could argue that this should perhaps be interpreted as a rhetorical strategy, aiming to show the book's historical significance, rather than as a statement about the book's originality. The same, however, cannot be said of the various other authors we have discussed here. A good example is John Keill, whose methodological discussion

102 Newton, *The Principia*, 385; idem, *Principia* (ed. 1713), *Editoris praefatio*, b2.

103 Idem, *The Principia*, 386; idem, *Principia* (ed. 1713), *Editoris praefatio*, b2^v. See idem, *The Principia*, 393; idem, *Principia* (ed. 1713), *Editoris praefatio*, c2 for the term “Newtonian philosophy.”

was, as we have seen, very detailed and very polemical. Yet there is no indication that Keill attempted to create an image of best practice centred around Newton. On the contrary, Keill mentions Newton only as representing one of the five particular approaches he discussed, the “writers of the mathematical philosophy” as distinguished from the other four approaches which met his definition of a “sect,” a term used in a similarly disparaging way by Pitcairne. Keill grouped Newton with other mathematicians in a list going back as far as Archimedes. There is no indication that this group was created to shower glory specifically on Newton: certainly it was aimed also to bestow prestige on David Gregory, Keill’s mentor and the last name on his list. And, obviously, Keill had an eye to enhancing his own reputation by referring to the authors in the list as his peers.

Such lists, which we can find in the polemical writings of Cheyne, Gregory, and Mead, amongst others, certainly do not testify to a perception of Newton’s approach in the *Principia* as fundamentally new or particular to Newton. Rather, it was not the method, but the execution and the results attained by Newton that made the greatest impression on these readers. We have found that the readers in the period considered here – again, with the notable exception of Freind – used specific elements for their own polemical purposes, but did not try to distil a particular methodology out of the pages of the *Principia*. This is what Cotes would do with his pointed references to a specifically “Newtonian philosophy,” thus setting the precedent for many others to follow during the rest of the eighteenth century. That this difference is real is demonstrated, too, by the fact mentioned earlier that the term “Newtonian” was not in general use in the period considered, except in a very limited number of cases to refer to aspects of Newton’s mathematics and physical theories.

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