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ISAAC NEWTON: PHILOSOPHICAL WRITINGS

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ISAAC NEWTON

Philosophical Writings

EDITED BY
ANDREW JANIAK
Duke University

Revised Edition

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Introduction

> In the preceding books I have presented principles of philosophy that are not, however, philosophical but strictly mathematical – that is, those on which the study of philosophy can be based. These principles are the laws and conditions of motions and of forces, which especially relate to philosophy. But in order to prevent these principles from becoming sterile, I have illustrated them with some philosophical scholia, treating topics that are general and that seem to be the most fundamental for philosophy, such as the density and resistance of bodies, spaces void of bodies, and the motion of light and sounds. It still remains for us to exhibit the system of the world from these same principles.
>
> . . . to treat of God from phenomena is certainly a part of natural philosophy.
>
> – Isaac Newton[1]

Newton as natural philosopher

Isaac Newton's influence is ubiquitous 300 years after his death. We employ Newtonian mechanics in a wide range of cases, students world-wide learn the calculus that he co-discovered with Leibniz, and the law of universal gravitation characterizes what is still considered a fundamental force. Indeed, the idea that a force can be "fundamental," irreducible to any other force or phenomenon in nature, is largely due to Newton, and

[1] The first passage is from the preface to Book III of the *Principia*, and the second is from its General Scholium, which was added to the second edition of the text in 1713 (793 and 943 of *Principia*, respectively).

still has currency in the twenty-first century. Remarkably, Newton's status as a theorist of motion and of forces, and his work as a mathematician, is equaled by his status as an unparalleled experimentalist. His experiments in optics, for instance, would be enough to guarantee his place in the early modern canon. Because of these achievements, Newton is regularly mentioned along with figures like Copernicus and Galileo as a founder of modern science. One might even contend that Newton helped to shape the very idea of the modern "scientist."

Despite these important facts, we should resist the temptation to think of Newton as a scientist in any straightforward sense. At a meeting of the British Association for the Advancement of Science in June of 1833, the Cambridge philosopher William Whewell coined the word "scientist." At the meeting, Whewell said that, just as the practitioners of art are called "artists," the practitioners of science ought to be called "scientists," indicating that they should no longer be called philosophers.[2] Indeed, before the early nineteenth century, people like Newton were called "philosophers," or, more specifically, "natural philosophers." This is not mere semantics. This fact of linguistic history reflects a deeper conceptual point: during the seventeenth century, and well into the eighteenth, figures like Newton worked within the centuries-old tradition of natural philosophy.[3]

[2] Whewell was responding to Samuel Taylor Coleridge's plea that the members of the British Association stop calling themselves "natural philosophers," for the scope of their research had narrowed considerably in recent years. For details, see Laura Snyder, *The Philosophical Breakfast Club* (New York: Broadway, 2011), 1–7. The first time that "scientist" was used in print was a year later, when Whewell – in an anonymous review – discussed the outcome of the British Association meeting in his review of Mary Somerville's book, *On the Connexion of the Physical Sciences* (*The Quarterly Review* 51 [1834], 59). The word "science," which derives from the Latin term "scientia" (meaning, roughly, knowledge), has been in continuous use in numerous contexts since the fourteenth century, but it did not obtain its modern meaning until the mid-to-late nineteenth century. Thus the new meaning of "science," referring to the natural sciences specifically, arose roughly at the time that the word "scientist" was coined (the OED has the new meaning of "science" first appearing in 1867).

[3] Two recent studies of the discipline of natural philosophy are Roger French and Andrew Cunningham, *Before Science: The Invention of the Friars' Natural Philosophy* (Brookfield: Scholar's Press, 1996), and Edward Grant, *A History of Natural Philosophy* (Cambridge University Press, 2007). For interpretations of Newton's work in natural philosophy, see Howard Stein, "Newton's Metaphysics," in *The Cambridge Companion to Newton*, ed. I. Bernard Cohen and George Smith (Cambridge University Press, 2002), ch. 8, and, more recently, Andrew Janiak, *Newton as Philosopher* (Cambridge University Press, 2008), Mary Domski, "Newton's Empiricism and Metaphysics," *Philosophy Compass* 5 (2010), 525–34, and Steffen Ducheyne, *The Main Business of Natural Philosophy* (Dordrecht: Springer, 2012). For a different perspective on Newton's status as a natural philosopher or a scientist, see Cohen and Smith's introduction to the *Cambridge Companion*, 1–4.

The modern disciplines of physics, chemistry, biology and so on had not yet been formed. Philosophers who studied nature investigated such things as planetary motions and the possibility of a vacuum, but they also discussed many aspects of human beings, including the psyche, and how nature reflects its divine creator. As the title of Newton's magnum opus, *Mathematical Principles of Natural Philosophy*, suggests, he intended his work to be in dialogue with Descartes's *Principles of Philosophy* (1644), a complex text that includes discussions of everything from the laws of nature to the nature of God's causal influence on the world. Just as Descartes had sought to replace Aristotelian or "Scholastic" methods and doctrines in natural philosophy, Newton intended his work to replace Descartes's. It is therefore illuminating to interpret Newton within the historical stream of natural philosophy.

Natural philosophy in the Aristotelian traditions of the thirteenth through the sixteenth centuries involved an analysis of Aristotle's ideas about causation within the natural world, especially within the Christianized context of the medieval period. Philosophers studying nature were often actually studying texts – such as commentaries on Aristotle – rather than conducting experiments or engaging in observations, and they rarely employed mathematical techniques. In the seventeenth century, natural philosophers like Galileo, Boyle, Descartes, and Newton began to reject not only the doctrines of the Aristotelians, but their techniques as well, developing a number of new mathematical, conceptual and experimental methods. Newton respected Descartes's rejection of Aristotelian ideas, but argued that Cartesians did not employ enough of the mathematical techniques of Galileo, or of the experimental methods of Boyle, in trying to understand nature. Of course, these developments have often been regarded as central to the so-called Scientific Revolution. Despite the centrality of these changes during the seventeenth century, however, the *scope* of natural philosophy had not changed. Natural philosophers like Newton expended considerable energy trying to understand, e.g., the nature of motion, but they regarded that endeavor as a component of an overarching enterprise that also included an analysis of the divine being.

Newton was a natural philosopher – unlike Descartes, he was not a founder of modern philosophy, for he never wrote a treatise of the order of the *Meditations*. Nonetheless, his *influence* on philosophy in the eighteenth century was profound, extending well beyond the bounds of philosophers studying nature, encompassing numerous figures and traditions in Britain, on the Continent, and even in the new world.[4] Newton's influence has at least two salient aspects. First, Newton's achievement in the *Opticks* and in the *Principia* was understood to be of such philosophical import that few philosophers in the eighteenth century ignored it. Most of the canonical philosophers in this period sought to interpret various of Newton's epistemic claims within the terms of their own systems, and many saw the coherence of their own views with those of Newton as a criterion of philosophical excellence. Early in the century, Berkeley grappled with Newton's work on the calculus in *The Analyst* and with his dynamics in *De Motu*, and he even discussed gravity, the paradigmatic Newtonian force, in his popular work *Three Dialogues between Hylas and Philonous* (1713). When Berkeley lists what philosophers take to be the so-called primary qualities of material bodies in the *Dialogues*, he remarkably adds "gravity" to the more familiar list of size, shape, motion, and solidity, thereby suggesting that the received view of material bodies had already changed before the second edition of the *Principia* had circulated widely. Hume interpreted Newtonian natural philosophy in an empiricist vein and noted some of its broader implications in his *Treatise of Human Nature* (1739) and *Enquiry Concerning Human Understanding* (1750). On the Continent, Kant attempted to forge a philosophically robust mediation between Leibnizian metaphysics and Newtonian natural philosophy, discussing Newtonian science at length in his *Metaphysical Foundations of Natural Science* (1786).[5]

Newton's work also served as the impetus for the extremely influential correspondence between Leibniz and the Newtonian Samuel Clarke

[4] See "Newton and Newtonianism," a special issue of *The Southern Journal of Philosophy* 50 (September 2012), edited by Mary Domski, which contains details of Newton's connections to figures such as Descartes, Spinoza, Wolff, and Kant. For a broader perspective on Newton's influence on the eighteenth century, see "Isaac Newton and the Eighteenth Century," *Enlightenment and Dissent* 25 (2009), ed. Stephen Snobelen.

[5] See the detailed account of Kant's reflections on Newtonian science in Michael Friedman, *Kant's Construction of Nature: A Reading of the Metaphysical Foundations of Natural Science* (Cambridge University Press, 2012).

early in the century, a correspondence that proved significant even for thinkers writing toward the century's end. Unlike the *vis viva* controversy and other disputes between the Cartesians and the Leibnizians, which died out by the middle of the century, the debate between the Leibnizians and the Newtonians remained philosophically salient for decades, serving as the impetus for Emilie Du Châtelet's influential work during the French Enlightenment, *Foundations of Physics* (1740), and also as one of the driving forces behind Kant's development of the "critical" philosophy during the 1770s, culminating in the *Critique of Pure Reason* (1781). Newton's work also spawned an immense commentarial literature in English, French, and Latin, including John Keill's *Introduction to Natural Philosophy* (1726), Henry Pemberton's *A View of Sir Isaac Newton's Philosophy* (1728), Voltaire's *Elements of the Philosophy of Newton* (1738), Willem 's Gravesande's *Mathematical Elements of Natural Philosophy* (1747), Colin MacLaurin's *An Account of Sir Isaac Newton's Philosophical Discoveries* (1748), which probably influenced Hume, and Du Châtelet's and Clairaut's commentary on Newton's *Principia* (1759). These and other commentaries were printed in various editions, were translated into various languages, and were often influential.

A second aspect of Newton's influence involves thinkers who attempted in one way or another to articulate, follow, or extend, the Newtonian "method" in natural philosophy when treating issues and questions that Newton ignored. Euclidean geometry and its methods were seen as a fundamental epistemic model for much of seventeenth-century philosophy – Descartes's *Meditations* attempts to achieve a type of certainty he likens to that found in geometry, and Spinoza wrote his *Ethics* according to the "geometrical method." Propositions deduced from axioms in Euclidean geometry were seen as paradigm cases of knowledge. We might see Newton's work as providing eighteenth-century philosophy with one of its primary models, and with a series of epistemic exemplars as well. David Hume is perhaps clearest about this aspect of Newton's influence. His *Treatise* of 1739 has the subtitle "An Attempt to Introduce the Experimental Method of Reasoning Into Moral Subjects," and there can be little doubt that he meant the method of the *Opticks* and the *Principia*. Indeed, as Hume's text makes abundantly clear, various eighteenth-century philosophers, including not only Hume in Scotland but Jean-Jacques Rousseau on the Continent, were taken to be, or attempted to become, "the Newton of the mind."[6] For Hume, this meant following what he took to be Newton's empirical method by providing the proper description of the relevant natural phenomena and then finding the most general principles that account for them. This method would allow us to achieve the highest level of knowledge attainable in the realm of what Hume calls "matters of fact."[7]

Despite the influence of Newton's "method" on eighteenth-century philosophy, it is obvious that the *Principia*'s greater impact on the eighteenth century is to have effected a branching within natural philosophy that led to the development of mathematical physics on the one hand, and philosophy on the other. And yet to achieve an understanding of how Newton himself approached natural philosophy, we must carefully bracket such historical developments. Indeed, if we resist the temptation to understand Newton as working within a well-established discipline called mathematical physics, if we see him instead as a philosopher studying nature, his achievement is much more impressive, for instead of contributing to a well-founded field of physics, he had to begin a process that would eventually lead natural philosophy to be transformed into a new field of study. This transformation took many decades, and involved a series of methodological and foundational debates about the proper means for obtaining knowledge about nature and its processes. Not only did Newton himself engage in these debates from his very first publication in optics in 1672, his work in both optics and in the *Principia* generated some of the most significant discussions and controversies in the late seventeenth and early eighteenth centuries. These debates concerned such topics as the proper use of hypotheses, the nature of space and time, and the appropriate rules for conducting research in natural philosophy. Newton's achievement was in part to have vanquished both Cartesian and Leibnizian approaches to natural

[6] Surprisingly, Kant declared that Rousseau was "the Newton of the mind" – for discussion, see Susan Neiman, "Metaphysics, Philosophy: Rousseau on the Problem of Evil," in *Reclaiming the History of Ethics: Essays for John Rawls*, ed. Andrews Reath, Barbara Herman and Christine Korsgaard (Cambridge University Press, 1997).

[7] A proposition expressing a matter of fact cannot be known to be true without appeal to experience because, unlike in the case of "relations of ideas," the negation of the proposition is not contradictory. For discussion of Hume's relation to Newton, with citations to the voluminous literature on that topic, see Graciela De Pierris, "Newton, Locke and Hume," in *Interpreting Newton: Critical Essays*, ed. Andrew Janiak and Eric Schliesser (Cambridge University Press, 2012).

philosophy; in the eighteenth century, and indeed much of the nineteenth, physics was largely a Newtonian enterprise. But this achievement, from Newton's own perspective, involved an extensive, lifelong series of philosophical debates. I discuss several of them in what follows.

Newton's career and correspondence

Isaac Newton was born into a rural family in Woolsthorpe, Lincolnshire on Christmas Day of 1642, the year of Galileo's death.[8] Newton's philosophical training and work began early in his intellectual career, while he was an undergraduate at Trinity College, Cambridge in the early 1660s. The notebooks that survive from that period[9] indicate his wide-ranging interests in topics philosophical, along with a reasonably serious acquaintance with the great "moderns" of the day, including Boyle, Hobbes, Gassendi, and especially Descartes. Later in his life, Newton corresponded directly with a number of significant figures in natural philosophy, including Boyle, Huygens, and Leibniz, and he developed personal relations with many others, including Henry More and John Locke. Newton's primary works, of course, are *Philosophiae Naturalis Principia Mathematica* – or *Mathematical Principles of Natural Philosophy* – and the *Opticks*. Each went through three successive editions during Newton's lifetime, which he oversaw under the editorship of various colleagues, especially Richard Bentley, Samuel Clarke, and Roger Cotes, two of whom became important Newtonians in their own right.[10]

[8] By the old calendar; other dates throughout this volume are given according to the new calendar.
[9] See J. E. McGuire and Martin Tamny (eds.), *Certain Philosophical Questions: Newton's Trinity Notebook* (Cambridge University Press, 1983).
[10] The *Principia* first appeared in 1687, ran into its third edition in 1726, just before Newton's death, and was translated into English by Andrew Motte in 1729; the Motte translation – as modified by Florian Cajori in a 1934 edition – remained the standard until I. Bernard Cohen and Anne Whitman published their entirely new version in 1999 (selections in this volume are from this edition; see the Note on texts and translations below). It also appeared in 1759 in an influential French translation by Emilie du Châtelet, the famous French Newtonian; remarkably, her translation remains the standard in French to this day. The *Opticks* first appeared in 1704, ran into its third edition in 1721, and was translated into Latin in 1706 by Samuel Clarke, Newton's famous defender in the correspondence with Leibniz; the Clarke translation ensured the text's accessibility on the Continent. There are many salient differences between Newton's two great works despite the tremendous influence each had on subsequent research in their respective fields in the eighteenth century and beyond. As I. Bernard Cohen has argued, Newton's choice of the vernacular rather than Latin for the presentation of his optical views

In addition to his published works and unpublished manuscripts, Newton's correspondence was extensive. It is important to remember that in Newton's day, intellectual correspondence was not seen solely, or perhaps even primarily, as a private affair between two individuals. It was viewed in much less constrained terms as a type of text that had an important public dimension, not least because it served as the primary vehicle of communication for writers separated by what were then considered to be great distances. As the thousands of letters sent to and from the Royal Society in Newton's day testify, science and philosophy would have ceased without this means of communicating ideas, results, and questions. It was therefore not at all unusual for letters between famous writers to be published essentially unedited. The Leibniz–Clarke correspondence was published almost immediately after Leibniz's death in 1716, Newton's correspondence with Richard Bentley was published in the mid-eighteenth century, and several of the letters reprinted in this volume were published in various journals and academic forums – including the Royal Society's *Philosophical Transactions* – in the late seventeenth and early eighteenth century.[11]

Early work in optics

In three significant respects, Newton's earliest work in optics – published in the *Philosophical Transactions* of the Royal Society beginning in 1672 – set the stage for important themes of his lifelong career in natural philosophy. Firstly, Newton's letter to the Society's secretary, Henry Oldenburg, often called the "New theory about light and colours," generated an immediate, extensive, and protracted debate that eventually involved important philosophers such as Robert Hooke in Britain and Christiaan Huygens, G. W. Leibniz and Ignatius Pardies on the Continent. Newton consistently regarded these figures not merely

may reflect his opinion that English was more appropriate for a field like optics, which had not yet achieved the same status as the science of the *Principia*, in part because it had not yet been sufficiently mathematized.

11 Of course, there were exceptions: most prominently, perhaps, is Newton's private correspondence with John Locke concerning "two notable corruptions of Scripture" that concerned the underpinnings of Newton's belief that the standard doctrine of the Trinity was a corruption of the original version of Christianity. See Newton's extremely long letter of November 14, 1690 in *The Correspondence of Isaac Newton*, ed. Herbert Turnbull, John Scott, A. R. Hall, and Laura Tilling (Cambridge University Press, 1959–77), vol. III, 83–129.

as disagreeing with his views, but as misinterpreting them. This experience helped to shape Newton's famous and lifelong aversion to intellectual controversy, a feature of his personality that he often mentioned in letters, and one that he would never outgrow. Secondly, because Newton regarded himself as misinterpreted by his critics, he had recourse to meta-level or methodological discussions of the practice of optics and of the kinds of knowledge that philosophers can obtain when engaging in experiments with light. The novelty and power of Newton's work in the *Principia* years later would eventually generate similar controversies that led Newton to analogous kinds of methodological discussions of his experimental practice within natural philosophy and of the kinds of knowledge that one can obtain in that field using either experimental or mathematical techniques. From *our* point of view, Newton's science was unusually philosophical for these reasons. Thirdly and finally, in his earliest optical work Newton began to formulate a distinction that would remain salient throughout his long intellectual career, contending that a philosopher must distinguish between a conclusion or claim about some feature of nature that is derived from experimental or observational evidence, and a conclusion or claim that is a mere "hypothesis," a kind of speculation about nature that is not, or not yet anyway, so derived. Newton's much later proclamation in the second edition of the *Principia* (1713), "*Hypotheses non fingo*," or "I feign no hypotheses," would infuriate his critics just as much as it would prod his followers into making the pronouncement a central component of a newly emerging Newtonian method.

The field of optics has its origins in the Ancient Greek period, when figures like Euclid and Ptolemy wrote works on the subject, but they focused less on light than on the science of vision, analyzing (e.g.) the visual rays that were sometimes thought to extrude from the eye, enabling it to perceive distant physical objects. In the early modern period, Kepler and Descartes each made fundamental contributions to the field, including the discovery of the inversion of the retinal image (in the former case) and an explanation of refraction (in the latter case). Newton's work helped to shift the focus of optics from an analysis of vision to an investigation of light. In "New Theory about Light and Colours," published in the *Philosophical Transactions* in 1672, Newton presented a number of experiments in which sunlight was allowed to pass through one or two prisms in order to probe some of its basic features. But what counts as a *feature* of light? Numerous philosophers during the seventeenth century, including Hooke and Huygens, developed doctrines concerning the fundamental physical nature of light in answer to the question: is light a stream of particles (or "corpuscles"), or is it a wave? This question obviously continued to have relevance into the twentieth century, when wave–particle duality was discovered. In his experiments with the prism, however, Newton sought to investigate something else, viz. what he calls "the celebrated *Phenomena of Colours*." Newton's various prism experiments, which he describes in considerable depth, suggested to him a "Doctrine" that he expresses in thirteen consecutive numbered propositions. Included in these propositions are the following claims about features of rays of light: first, the rays of light that emerge when sunlight passes through a prism exhibit various colors; second, these colors differ in their "degrees of Refrangibility," which means that they exhibit and retain an index of refraction, even when they are passed through a second prism; third, these colors – or colorful rays – are not modifications of sunlight itself, but rather are "*Original* and *connate properties*" of it; and, fourth, this means that although ordinary sunlight appears white, or perhaps colorless, to our perception, it actually contains numerous colors within it, which can be experimentally revealed.

Newton's paper exhibits what a contemporary reader would regard as an intriguing blend of experimental evidence and philosophical argumentation. The latter hinges on Newton's interpretation of the concept of a property or a quality, as the following passage, which follows the "Doctrine" expressed in thirteen propositions, tellingly reveals:

> These things being so, it can be no longer disputed, whether there be colours in the dark, nor whether they be the qualities of the objects we see, no nor perhaps, whether Light be a Body. For, since Colours are the *qualities* of Light, having its Rays for their entire and immediate subject, how can we think those Rays *qualities* also, unless one quality may be the subject of and sustain another; which in effect is to call it *substance*. We should not know Bodies for substances, were it not for their sensible qualities, and the Principal of those being now found due to something else, we have as good reason to believe that to be a substance also. (This volume, p. 11)

Newton argues as follows here: since rays of light have colors as basic features, we should regard these colors as qualities or properties of the rays; but doing so requires us to think of the rays as bearers of qualities, which is to say, as substances in their own right. And if rays of light are substances, this means that we cannot also think of them as qualities or properties of anything else – a point that follows from a widely accepted notion of a substance at the time, one easily found in Descartes, among others.[12] And if we cannot think of rays of light as properties or qualities, then they are not waves, for waves are features of some medium (think of waves on the surface of a lake). Light must be a stream of particles.

This line of argument became one of the centerpieces of the debate that Newton's paper generated. In some parts of his paper, when Newton wrote of the "rays" of light, he had evidently intended to remain neutral on whether the rays are particles or waves (this is reminiscent of the ancient Greek practice of avoiding physical discussions of visual rays). But then toward the paper's end, Newton added his new line of argument, which employed some philosophical analysis together with some experimental evidence to support the conclusion that rays of light cannot be waves after all. Newton's critics pounced. This led to the first problem he encountered in response to his paper: what he calls his "theory" of light and colors was not merely rejected, but rather immediately misunderstood, at least from his own perspective. Just days after Newton's paper was read at the Royal Society, Robert Hooke responded with a detailed letter to Oldenburg. In the first few sentences, Hooke indicates that, from his point of view, Newton's "Hypothesis of saving the phenomena of colours" essentially involves the contention that rays of light are particulate, rather than wavelike.[13] Hooke argues, in contrast, that light "is nothing but a pulse or motion propagated through an homogeneous, uniform and transparent medium;" that is, he argues that light is indeed wavelike. He makes it perfectly clear, moreover, that his hypothesis can save the phenomena of colours just as well as Newton's, which is to say, that his hypothesis is compatible with the experimental evidence Newton gathers. Evidently, the line of argument in the passage quoted above caught Hooke's eye. Among philosophers,

[12] Newton would have been familiar with the discussion of substances in Descartes, *Principles of Philosophy*, part 1: §§51–53.

[13] See Hooke to Oldenburg, February 15, 1671/2, in *Correspondence of Isaac Newton*, vol. 1, 113. In recounting Newton's theory, Hooke does mention the points about refrangibility and heterogeneity, but he thinks that Newton's "first proposition" is "that light is a body" and that differently colored rays of light are in fact "several sorts of bodies." I take this to represent Hooke's interpretation of how Newton can account for the data with the theory that light consists of particles.

he was not alone. In a letter to Huygens explaining Newton's theory of light, Leibniz writes that Newton takes light to be a "body" propelled from the sun to the earth which, according to Leibniz, Newton takes to explain both the differential refrangibility of rays of light and the phenomena of colors.[14]

After the extensive correspondence, and controversy, generated in response to Newton's early optical views and experiments, he often threatened to avoid engaging in mathematical and philosophical disputes altogether. He insisted to friends and colleagues that he found intellectual controversy unbearable. Fortunately for us, he never followed through with his threat to disengage from discussions in natural philosophy, and sent many important letters in his later years. One of his more important pieces of correspondence after the optics controversy was with the natural philosopher Robert Boyle in 1679 (Newton's letter was published for the first time in the mid-eighteenth century).[15] In his lengthy letter to Boyle, Newton presents his speculations concerning various types of what we would now call chemical interactions; many of these speculations bear similarities to passages that appeared years later in the queries to the *Opticks*. The letter is also famous for presenting one of Newton's early speculations concerning how gravity might be physically explained; it presents, among other things, a picture of what Newton would countenance as a viable explanation of gravity in physical terms. This issue became of paramount importance once the *Principia* appeared.

Newton's relation to Descartes

Like many philosophers who worked in the wake of Galileo and of Descartes, Newton never seriously analyzed Aristotelian ideas about

[14] In *Oeuvres complètes de Christiaan Huygens*, ed. Johan Adriaan Vollgraff (The Hague: Nijhoff, 1888–1950), vol. x, 602. Ignatius Pardies, another of Newton's interlocutors, similarly found it difficult to differentiate the claim about the corporeal nature of light from Newton's ideas concerning refrangibility and heterogeneity. See his two letters to the Royal Society concerning Newton's work, both of which are reprinted in *Isaac Newton's Papers and Letters on Natural Philosophy*, ed. I. Bernard Cohen and Robert Schofield, revised edn (Cambridge, MA: Harvard University Press, 1978,); cf. the discussion of Pardies in A. I. Sabra, *Theories of Light from Descartes to Newton*, 2nd edn (Cambridge University Press, 1981), 264–7.

[15] The letter to Boyle first appeared in *The Works of the Honourable Robert Boyle*, ed. Thomas Birch (London, 1744), vol. i, 70–4.

nature. As is especially clear from the unpublished anti-Cartesian tract, *De Gravitatione* (see below), Newton expended considerable energy engaging with Cartesian ideas,[16] and when he published the first edition of the *Principia* in 1687, Cartesianism remained the reigning view in natural philosophy and served as the backdrop for much important research.[17] This feature of the intellectual landscape persisted for many years: Cotes's famous and influential preface to the second edition of the *Principia* – see chapter IV below – indicates that Cartesianism remained a primary competitor to Newton's natural philosophy in 1713. Despite the astonishing impact that Newton's work had on various fields, including of course what we would call philosophy proper, it would be anachronistic to conclude that Newtonianism had replaced its primary competitor, for Cartesianism's influence did not dissipate until some time after Newton's death in 1727.

As *De Gravitatione* shows, Newton not only read Descartes's *Principles of Philosophy* carefully, he attempted to refute some of the central notions in that text. *De Gravitatione* raises a number of controversial interpretive issues, including first and foremost the provenance of the text itself. No consensus has emerged as to the dating of the manuscript – which remained unpublished until 1962 – and there is insufficient evidence for that question to be answered as of now,[18] but two things remain clear:

[16] In his library, Newton had a 1656 Amsterdam edition of Descartes's *Principles*, along with a 1664 London edition of the *Meditations*. On Newton's relation to Descartes and to Cartesianism, see the classic treatments in the chapter "Newton and Descartes" in Alexandre Koyré, *Newtonian Studies* (Cambridge, MA: Harvard University Press, 1965), and in Stein, "Newton's Metaphysics."

[17] See John Heilbron, *Elements of Early Modern Physics* (Berkeley: University of California Press, 1982), 30. Even in Newton's home university, Cambridge, and alma mater, Trinity College, his works and ideas did not displace those of the Cartesians within the standard curriculum until roughly 1700; indeed, Cartesianism was so popular that the Vice-Chancellor of Cambridge University, Edmund Boldero, decreed in November 1688 that undergraduates could no longer base their disputations on Descartes, but had to use Aristotle instead (see John Gascoigne, *Cambridge in the Age of the Enlightenment* (Cambridge University Press, 1985), 54–5 and 143–5). Part of the shift toward Newtonian ideas reflected the growing influence of Richard Bentley, who became Master of Trinity in 1700, a post he retained for decades. Roger Cotes, whom Bentley chose to be the editor of the second edition of the *Principia* in 1709, entered Trinity in 1699 and became a fellow in 1705.

[18] The text first appeared, in a transcription of the original Latin and an English translation, in *Unpublished Scientific Writings of Isaac Newton*, ed. A. R. Hall and Marie Boas Hall (Cambridge University Press, 1962). In the Halls' judgment, the text is juvenile and probably originates in the period from 1664 to 1668. In an influential interpretation, Betty Jo Teeter Dobbs contends, in contrast, that the work is mature and was written in late 1684 or early 1685, while Newton was preparing the first edition of the *Principia*. See Dobbs, *The Janus Faces of Genius: The Role of*

first, the text is an extended series of criticisms of Cartesian natural philosophy; and, second, it is significant for understanding Newton's thought, not least because it represents a sustained philosophical discussion. *De Gravitatione* helps to dispel the easily informed impression that Newton sought, in the *Principia*, to undermine a Leibnizian conception of space and time, as his defender, Samuel Clarke, would attempt to do years later in the correspondence of 1715–16. Although Leibniz did eventually express what became the canonical early modern formulation of relationalism concerning space and time – the view, roughly, that space is nothing but the order of relations among physical objects, and time nothing over and above the succession of events involving those objects – and although Newton and Clarke were highly skeptical of such a view, it is misleading to read the *Principia* through the lens provided by the later controversy with the Leibnizians. Newton's extensive attempt in *De Gravitatione* to refute Descartes's conception of space and time in particular indicates that the Scholium should be read as providing a replacement for the Cartesian conception.[19] Newton had a Cartesian, and not a Leibnizian, opponent primarily in mind when he wrote his famous articulation of "absolutism" concerning space and time. It may be thought a measure of Newton's success against his Cartesian predecessors that history records a debate between the Leibnizians and the Newtonians as influencing every subsequent discussion of space and time in the eighteenth century and beyond.

Mathematical Principles of Natural Philosophy

As is the stuff of legend, in August of 1684, Edmond Halley – for whom the comet is named – came to visit Newton in Cambridge in order to discover his opinion about a subject of much dispute in celestial mechanics. At this time, many in the Royal Society and elsewhere were at work on a cluster of problems that might be described as follows: how

Alchemy in Newton's Thought (Cambridge University Press, 1991), 141–6, where she also reviews various alternative opinions on the matter. In a recent essay, Jim Ruffner raises important doubts concerning earlier interpretations, concluding that the text must have been written before Halley's famous visit to Newton in 1684 – see "Newton's *De gravitatione*: A Review and Reassessment," *Archive for the History of the Exact Sciences* 66 (2012).

[19] Stein presents this interpretation of Newton's *Principia* in his classic essay, "Newtonian Space-Time," in *The Annus Mirabilis of Sir Isaac Newton 1666–1966*, ed. Robert Palter (Cambridge, MA: MIT Press, 1970).

can one take Kepler's Laws, which were then considered among the very best descriptions of the planetary orbits, and understand them in the context of dynamical or causal principles? What kind of cause – for some, what kind of *force* – would lead to planetary orbits of the kind described by Kepler? In particular, Halley asked Newton the following question: what kind of curve would a planet describe in its orbit around the sun if it were acted upon by an attractive force that was inversely proportional to the square of its distance from the sun? Newton immediately replied that the curve would be an ellipse (rather than, say, a circle).[20] Halley was amazed that Newton had the answer at the ready. But Newton also said that he had mislaid the paper on which the relevant calculations had been made, so Halley left empty handed. He would not be disappointed for long. In November of that year, Newton sent Halley a nine-page paper, entitled *De Motu* (on motion), that presented the sought-after demonstration, along with several other advances in celestial mechanics. Halley was delighted, and immediately returned to Cambridge for further discussion. It was these events that precipitated the many drafts of *De Motu* that eventually became *Principia mathematica* by 1686. Several aspects of the *Principia* have been central to philosophical discussions since its first publication, including Newton's novel methodology in the book, his conception of space and time, and his attitude toward the dominant orientation within natural philosophy in his day, the so-called mechanical philosophy.

Methodology

When Newton wrote the *Principia* between 1684 and 1686, he was not contributing to a preexisting field of study called mathematical physics; he was attempting to show how philosophers could employ various mathematical and experimental methods in order to reach conclusions about nature, especially about the motions of material bodies. In his

[20] Although astronomers for centuries had thought that the planetary orbits must be circular, for various important reasons, in the seventeenth century Kepler had argued that they are in fact elliptical (although this is consistent with the idea, which became important in later contexts, that the orbits are nearly circular). This innovation proved to be crucial for later work in celestial mechanics. Ellipses are figures in which a straight line from the center to any arbitrary point on the surface does not describe a single radius that is equal in length to all other radii. So they are more difficult to deal with geometrically than circles.

lectures presented as the Lucasian Professor, Newton had been arguing since at least 1670 that natural philosophers had to employ geometrical methods in order to understand various phenomena in nature.[21] The *Principia* represented his attempt to reorient natural philosophy, taking it in a direction that neither his Aristotelian predecessors, nor his Cartesian contemporaries, had envisioned. He did not immediately convince many of them of the benefits of his approach. Just as his first publication in optics in 1672 had sparked an intense debate about the proper methods for investigating the nature of light – and much else besides – his *Principia* sparked an even longer-lasting discussion about the methodology that philosophers should adopt when studying the natural world. This discussion began immediately with the publication of the *Principia*, and intensified considerably with the publication of its second edition in 1713, since many of Newton's alterations in that edition involved changes in his presentation of his methods. Discussions of methodology would eventually involve nearly all of the leading philosophers in England and on the Continent during Newton's lifetime.

Unlike Descartes, Newton placed the concept of a force at the very center of his thinking about motion and its causes within nature. In that regard, his reactions to the shortcomings of Cartesian natural philosophy parallel Leibniz's, who coined the term "dynamics." But Newton's attitude toward understanding the forces of nature involved an especially intricate method that generated intense scrutiny and debate amongst many philosophers and mathematicians, including Leibniz.[22] Newton's canonical notion of a force, which he calls a *vis impressa* or "impressed force," is the notion of an "action exerted on a body" that changes its state of motion. This was a confusing notion at the time. If you throw me a ball and I catch it, I have impressed a force on the ball, since I have changed its state of motion. We have a good idea of what I am, and of what the ball is, but what exactly is this "force" that I impressed on it? Is the force some physical item? Is it not physical? It does not seem likely that a force is itself a physical thing, or a substance, to use a philosophical notion popular in Newton's day (as we saw above in his first optics

[21] See the "Lectiones opticae" of 1670 in *The Optical Papers of Isaac Newton*, ed. Alan Shapiro (Cambridge University Press, 1984), vol. 1, 86–7.

[22] See Daniel Garber, "Leibniz, Newton and Force," in *Interpreting Newton*, ed. Janiak and Schliesser, ch. 2.

paper). In Definition Four in the *Principia*, which defines an impressed force for the first time, Newton remarks: "This force consists solely in the action and does not remain in a body after the action has ceased." So when I caught the ball, the force I impressed on it was the action of catching the ball, or an action associated with catching the ball, and not a property of me or of the ball after the action ceased. This idea confused many of Newton's readers. By the mid-eighteenth century, the time of Hume's analysis of causation in the *Treatise* and the *Enquiry*, many philosophers had started to think that actions and other kinds of event are important items to have in one's ontology, and they often contended that causal relations hold between events. But in Newton's day, philosophers typically regarded objects or substances as the causal relata. So actions were difficult to analyze or often left out of analyses.

Newton did try to clarify his method of characterizing forces. If one brackets the question of how to understand forces as ephemeral actions that do not persist after causal interactions have ceased, one can make progress by conceiving of forces as *quantities*. In particular, since Newton's eight definitions and three laws indicate that forces are proportional to mass and acceleration, and since mass – or the quantity of matter – and acceleration are both quantities that can be measured, Newton gives us a means of measuring forces. This is crucial to his method. If one thinks of forces as measurable quantities, moreover, then one can attempt to identify two seemingly disparate forces as in fact the same force through thinking about measuring them. Newton does this in Book III of the *Principia*, when he argues in proposition 5 and its Scholium that the centripetal force maintaining the planetary orbits is in fact gravity, viz., the force that causes the free fall of objects on earth. This culminates in the claim in proposition 7 that all bodies gravitate toward one another in proportion to their quantity of matter. This helped to unify what were once called superlunary and sublunary phenomena, a unification that was obviously crucial for later research in physics.

Despite his evident success in obtaining what we now call the law of universal gravitation, Newton admits that he lacks another kind of knowledge about gravity. In the General Scholium, he reminds his readers that gravity is proportional to a body's quantity of matter (its mass) and reaches across vast distances within our solar system, adding: "I have not as yet been able to deduce from phenomena the reason for these properties of gravity, and I do not feign hypotheses."[23] With this phrase, one of the most famous in all of Newton's writings, he returned to a key theme of his very first optical paper from forty years earlier, viz. the proper role of hypotheses and of hypothetical reasoning within natural philosophy.[24] Some of Newton's interpreters have regarded this phrase as signaling a strong commitment to the broad doctrine that all hypotheses concerning natural phenomena ought to be avoided on principle. This interpretation is sometimes coupled with the view that some British philosophers in the late seventeenth century regarded Cartesianism as overly reliant on hypotheses in reaching conclusions about phenomena. But this interpretation may be hard to square with Newton's texts. For instance, in the Scholium to proposition 96 of Book 1 of the *Principia*, Newton discusses hypotheses concerning light rays. Similarly, in query 21 of the *Opticks* (this volume, p. 170), he proposes that there might be an aether whose differential density accounts for the gravitational force acting between bodies. In light of such examples, one can read the General Scholium's pronouncement in this way: a philosopher concerned with explaining some feature of nature – such as the fact that gravity is inversely proportional to the *square* of spatial separation, rather than, say, the *cube* – may legitimately entertain and propose hypotheses for consideration by his readers, but he may not "feign" the hypothesis in the sense of taking it as having been established either through experiment, observation, or some form of reasoning. Hence Newton thinks that he has established the fact that gravity acts on all material bodies in proportion to their quantity of matter, but he has *not* established the existence of the aether. By the time of the General Scholium, Newton was increasingly embroiled in philosophical disputes with Leibniz. In order to account for the motions of the planetary bodies in his *Tentamen* of 1690, Leibniz introduces *ex hypothesi* the premise that some kind of fluid surrounds, and is contiguous to, the various planetary bodies, and then argues that this fluid must be in motion to account for

23 We owe this translation of the phrase to Alexandre Koyré, who first noted that Newton uses the word "feign" in a parallel discussion in English: *From the Closed World to the Infinite Universe* (Baltimore, MD: Johns Hopkins University Press, 1957), 229 and 299 n. 12.

24 For an influential discussion of the development in Newton's conception of hypotheses over time, see I. Bernard Cohen, "Hypotheses in Newton's Philosophy," *Physis: Rivista Internazionale di Storia della Scienza* 8 (1966), 163–84.

their orbits.[25] Newton would have argued that Leibniz had "feigned" the hypothesis of the vortices. A debate between the two philosophers on this score would bring them to the question of the mechanical philosophy: whereas Newton might object to Leibniz's reasoning on methodological grounds, Leibniz might reply that Newton's theory of gravity involves action at a distance, which his vortex hypothesis avoids (see below).

In addition to the General Scholium, the second edition of the *Principia* also included what Newton called "regulae philosophandi," or rules of philosophy (this volume, p. 108), which became the focal point of vigorous discussion and debate well into the eighteenth century. The first two rules concern causal reasoning, but it is the third rule that generated the most debate, for it involved both an aspect of Newton's controversial argument for universal gravity and also a rare public statement by Newton of what he regarded as the "foundation" of natural philosophy. The third rule concerns an induction problem: we have perceptions and experiments that provide us with knowledge of the objects and natural phenomena in our neck of the universe, but on what basis can we reach a conclusion concerning objects and phenomena throughout the *rest* of the universe? Newton himself reached such a conclusion about gravity in proposition 7 of Book III of the *Principia*. Part of Newton's answer is presented in rule 3: "Those qualities of bodies that cannot be intended and remitted [i.e., increased and diminished] and that belong to all bodies on which experiments can be made should be taken as qualities of all bodies universally" (this volume, p. 109). We know, say, that a clump of dirt has certain qualities such as extension and mobility, but how do we know that the entire earth has such qualities? It surely lies beyond the reach of our experiments, or at any rate, it did in Newton's day. Newton says that the sun and the earth interact according to his law of gravity, but how do we know that the sun contains a quantity of matter, that it is a material body with the same basic qualities that characterize the earth or the moon? Newton thinks that gravity reaches into the very center of the sun, but what did anyone in 1713 know about such things? Newton glosses his third rule in part as follows, connecting it with his laws of motion:

25 See the *Tentamen* in Gottfried Wilhelm Leibniz, *Mathematische Schriften*, ed. C. Gerhardt (Berlin, 1849), vol. VI, 149, and Domenico Bertoloni Meli, *Equivalence and Priority: Newton vs. Leibniz* (Oxford University Press, 1993), 128–9.

> That all bodies are movable and persevere in motion or in rest by means of certain forces (which we call forces of inertia) we infer from finding these properties in the bodies that we have seen. The extension, hardness, impenetrability, mobility, and force of inertia[26] of the whole arise from the extension, hardness, impenetrability, mobility, and force of inertia of each of the parts; and thus we conclude that every one of the least parts of all bodies is extended, hard, impenetrable, movable, and endowed with a force of inertia. And this is the foundation of all natural philosophy. (this volume, p. 109)

Many of Newton's readers in 1713 would have granted him the following inference: although we do not have any perceptions of, say, the interior of the earth, or even of many ordinary objects within our grasp, we can reasonably infer that everything with certain basic properties – something akin to what John Locke, borrowing a term of Robert Boyle's, called the "primary qualities" – at the macroscopic level is comprised of micro-particles that are characterized by those same basic properties. But at the end of his gloss of Rule 3, Newton applies this same (or analogous) reasoning to the force of gravity, arguing as follows: since we experience the fact that all bodies on or near the earth gravitate toward the earth – in cases such as free fall – and that the moon gravitates toward the earth, etc., we can infer that all bodies everywhere gravitate toward all other bodies. This argument would appear to suggest that gravity, which, as we have seen, is a kind of impressed force, an action, is somehow akin to qualities like extension and impenetrability. So is Newton suggesting that gravity is actually a *quality* of all bodies? This question became the subject of intense debate and remains so today.

The mechanical philosophy

Newton's second law indicates that a body moving rectilinearly will continue to do so unless a force is impressed on it. This is not equivalent to claiming that a body moving rectilinearly will continue to do so unless another body impacts upon it. A *vis impressa* – an impressed force – in Newton's system is not the same as a body, as we have seen; but what is

[26] This is a potentially confusing way of referring to the mass – specifically, what we would call the inertial mass – of a body. See Definition Three in this volume, p. 80.

more, some impressed forces need not involve contact between bodies at all. For instance, gravity is a kind of centripetal force, and the latter, in turn, is a species of impressed force. Hence a body moving in a straight line will continue to do so until it experiences a gravitational pull, even if no body impacts upon it. Indeed, the gravitational pull might originate with a mass that is millions of miles away. As we have seen, an impressed force is an action exerted on a body. Hence the gravity exerted on a moving body is an action (the Latin term is *actio*), which is obviously a causal notion. This is not an empirical claim per se; it is merely a reflection of Newton's laws, together with his notion of an impressed force, and his further idea that gravity is one kind of impressed force. These elements of the *Principia* make conceptual room for a causal interaction between two bodies separated by a vast distance. This became known in philosophical circles as the problem of action at a distance.[27]

Many of Newton's most influential contemporaries objected vigorously to the fact that his philosophy had made room for – if not explicitly defended – the possibility of distant action between material bodies. Leibniz and Huygens in particular rejected this aspect of Newton's work in the strongest terms, and it remained a point of contention between Newton and Leibniz for the rest of their lives (see below). Both Leibniz and Huygens were convinced that all natural change occurs through contact action, and that any deviation from this basic mechanist principle within natural philosophy would lead to serious difficulties, including the revival of outmoded Aristotelian ideas. By the seventh proposition of Book III of the *Principia*, as we have seen, Newton reached the following conclusion: "Gravity acts on all bodies universally and is proportional to the quantity of matter in each." Leibniz eventually accused Newton of regarding gravity as a kind of "occult quality," that is, as a quality of bodies that is somehow hidden within them and beyond the philosopher's understanding. Newton's gloss on Rule 3 only made matters worse from Leibniz's point of view, since it tacitly (or functionally) treats gravity as a kind of universal quality akin to extension or impenetrability. But unlike them, it was occult, imperceptible and unintelligible.

One would think that the criticisms of Leibniz and Huygens – both of whom were held in high regard by Newton early in his career – would

[27] For a classic treatment, see Mary Hesse, *Forces and Fields: The Concept of Action at a Distance in the History of Physics* (London: Nelson, 1961).

have pressed Newton into articulating an extensive defense of the possibility of action at a distance. Newton presented no such defense; moreover, there is actually evidence that Newton himself rejected the possibility of action at a distance, despite the fact that the *Principia* allows it as a conceptual possibility, if not an empirical reality. When Richard Bentley – later to become an important colleague of Newton and the Master of Newton's college in Cambridge – gave the first lectures on Christianity endowed by a bequest in Robert Boyle's will in late 1691, he sought Newton's advice in what became a celebrated correspondence (it is reproduced in this volume). Bentley's aim was to argue against atheism in part by appealing to the philosophical and theological consequences of what was at the time the newest theory of nature in England, viz., Newton's. In the course of explaining his views to Bentley, Newton made the following (now famous, if not infamous) pronouncement in a letter of 1693:

> It is inconceivable that inanimate brute matter should, without the mediation of something else which is not material, operate upon and affect other matter without mutual contact ... That gravity should be innate, inherent, and essential to matter, so that one body may act upon another at a distance through a vacuum, without the mediation of anything else, by and through which their action and force may be conveyed from one to another, is to me so great an absurdity that I believe no man who has in philosophical matters a competent faculty of thinking can ever fall into it. (This volume p. 137)

It certainly seems that Newton is uncomfortable with the very idea of action at a distance, although some historians and philosophers have argued strongly that there are other readings of the letter.[28] Rather than rejecting distant action between material bodies per se, he may have been rejecting a particular version of that idea. One motive for uncovering a

[28] Indeed, in recent years there has been a robust debate about the correspondence with Bentley in particular, and about Newton's attitude toward action at a distance in general, with many interpreters criticizing the account in Janiak, *Newton as Philosopher*. See, e.g., Steffen Ducheyne, "Newton on Action at a Distance and the Cause of Gravity," *Studies in History and Philosophy of Science* 42 (2011), 154–9; John Henry, "Gravity and *De Gravitatione*: The Development of Newton's Ideas on Action at a Distance," *Studies in History and Philosophy of Science* 42 (2011), 11–27; and Eric Schliesser, "Newton's Substance Monism, Distant Action, and the Nature of Newton's Empiricism," *Studies in History and Philosophy of Science* 42 (2011), 160–6. Cf. Janiak's reply to their criticisms in "Three Concepts of Cause in Newton," *Studies in History and Philosophy of Science* 44 (2013): 397–407.

nuanced interpretation of this letter is the obvious fact that Newton apparently regarded action at a distance as perfectly possible when writing the *Principia*. It is difficult to reconcile the *Principia* with the Bentley correspondence. One can argue that although he left open the possibility of action at a distance in his main work, Newton himself did not accept that possibility. The debate on such matters continues unabated.

Space and the divine

Unlike questions about Newton's methods and his apparent deviation from the norms established by mechanist philosophers like Descartes and Boyle, Newton's conception of space and time, along with his view of the divine being, did not immediately engender a philosophical debate. It was Leibniz more than any other philosopher who eventually succeeded in fomenting a philosophical debate in which the "Newtonian" conception of space, time, and the divine would play a central role (see below). But Leibniz's philosophical views were relatively unknown when Newton first formed his conception, and Newton never took Aristotelian philosophical views very seriously. It was instead Descartes's view of space, the world, and God, which he pondered in his youth, and like many contemporaries in Cambridge in those days, he encountered them within the context of Henry More's then famous discussions of Cartesianism (a term coined by More). Beginning with his correspondence with Descartes in 1648, and continuing with a series of publications in later years, many of which Newton owned in his personal library, More argued that Descartes made two fundamental mistakes: first, he wrongly contended that extension and matter are identical (and that the world is therefore a plenum); and second, he mistakenly believed that God and the mind were not extended substances, which made their causal interactions with such substances mysterious. Just as Princess Elisabeth of Bohemia raised fundamental objections to Cartesian dualism, More raised similar objections against the Cartesian view of the divine.[29] Descartes agreed with More's suggestion that God can act

[29] See Lisa Shapiro (ed.), *The Correspondence between Princess Elisabeth of Bohemia and René Descartes* (Chicago: University of Chicago Press, 2007), and Genevieve Lewis (ed.), *Descartes: Correspondance avec Arnauld et Morus, texte Latin et traduction* (Paris: Librairie philosophique Vrin, 1953).

anywhere on nature if he so chooses, and came very close to accepting More's contention that such a view entails that God must be present within the world wherever he in fact chooses to act. For how could God part the Red Sea, suggested More, unless God were present precisely where the Red Sea is located? Of course, More agreed that God is not made of parts, cannot be imagined, and cannot be affected by the causal activity of material bodies – the causal arrow flows only in one direction. But More concluded that God is extended in his own way. If one fixes Descartes's two basic mistakes, one obtains what More regarded as a proper philosophical view: space is distinct from matter because it is extended but penetrable, whereas matter is extended but impenetrable; and, in tandem, all substances are extended, but whereas some, such as tables and chairs, are impenetrable, others, such as the mind and even God, are penetrable and therefore not material.[30] Newton was deeply influenced both by More's criticisms of Descartes and by his positive philosophical conception of space and the divine.

In a number of texts, including *De Gravitatione*, the famous discussion of space and time in the Scholium to the *Principia*, and the discussion of God in the General Scholium, Newton made his generally Morean attitudes perfectly clear. He rejected the Cartesian identification of extension and matter, arguing that space itself exists independently of material objects and their relations, and he contended that all entities, including the human mind and even the divine being, are extended in the sense that they have spatial location, even if they are extended in ways that distinguish them from ordinary material bodies.[31] In Newton's hands, space becomes a fundamental concept of natural philosophy, which is foreign to Cartesians and (later) objectionable to Leibnizians. As Newton puts it in a famous

[30] For details of More's views, see the classic paper by Alan Gabbey, "Philosophia Cartesiana Triumphata: Henry More (1646–1671)," in *Problems of Cartesianism*, ed. Thomas Lennon et al. (Kingston and Montreal: McGill-Queen's University Press, 1982). For details on the Cartesian context, see the discussion in Jasper Reid, "The Spatial Presence of Spirits among the Cartesians," *Journal of the History of Philosophy* 46 (2008), 91–118. For further discussion of the Descartes-More correspondence and its possible influence on Newton, see Janiak, "Substance and Action in Newton and Descartes," *The Monist* 93 (October 2010), 657–77.

[31] This may mean that for Newton, two substances can be co-located: for discussion, see two recent papers by Hylarie Kochiras: "Gravity and Newton's Substance Counting Problem," *Studies in History and Philosophy of Science* 40 (2009), 267–80, and "Gravity's Cause and Substance Counting: Contextualizing the Problems," *Studies in History and Philosophy of Science* 42 (2011), 167–84.