chapter 1

life and times

If one picks up a book about Isaac Newton, one expects to find a character conforming to the legend. One expects to encounter a mathematician who invented calculus and employed its great analytical power for understanding natural phenomena. One expects to find a scientist who ignored the philosophical and metaphysical preoccupations of his predecessors, focusing on experimental and mathematical questions that form the nucleus of modern physics. One expects to learn of a rational thinker who scorned the religious superstitions and practices of his day, portending a new secular age in which science would reign as the surest route to knowledge of the natural world. But historians of science have long since recognized the profound gap between Newton the legend and Newton the actual historical figure (Cohen and Smith 2002, 1–6). As biographers of Newton have often suggested, one reason for this gap is that Newton was actually much more exercised about religion, theology, philosophy, and even alchemy than one would expect (Dobbs 1975, Manuel 1968, Westfall 1980). There is, however, a deeper reason for the gap, one connected intimately to the proper methodology for studying the history of science and philosophy: Newton lived in an era that is profoundly different from our own in the way that it organized human knowledge. Like his contemporaries, Newton thought about science and religion, theology and philosophy, nature and God in ways that are strikingly peculiar to any twenty-first century reader. Indeed, his thinking was different enough that he lacked any such categories, as did his contemporaries: the early moderns organized human knowledge in a way that is profoundly foreign to us. It is always a struggle to come to understand the work of any genius. But in Newton's case, we have the additional challenge of coming to understand his age.

Newton lived in tumultuous times. When he was born on Christmas Day in 1642, the historically stable British monarchy with centuries of tradition underpinning it was in crisis. A civil war had broken out, one that would lead to fundamental political and social change within the next two decades.

Newton, First Edition. Andrew Janiak.

By the time Newton was a young man, England had undergone not only civil war and a political revolution, but also the beheading of the King, the bloody rule of Oliver Cromwell, and the Restoration of the monarchy in 1660. These events had a deep impact on the most important philosophers working while Newton was a young man: in 1659, in a preface to one of his most important works on experiments with his air pump, Robert Boyle wrote of "the strange confusions of this unhappy nation" (Boyle 1999, vol. 1: 145). The revolution in politics and society was accompanied by equally profound developments in intellectual life. When Newton enrolled in Trinity College, Cambridge, in 1660, a traditional curriculum was still in place, but adventurous and talented students were directed to read the great *moderns* of the day, who were overthrowing the Scholastic tradition that had reigned for centuries in Europe's great universities. Many of the moderns were Newton's countrymen, including Thomas Hobbes, Robert Boyle, and Henry More, the latter being a friend of Newton's family and a key leader of the Cambridge Platonist movement in midcentury. Newton avidly read their works, along with the latest writings from philosophers on the Continent, especially Descartes and the Dutch mathematician Christiaan Huygens (McGuire and Tamny 1983). The political and intellectual spheres came together early in Newton's life with the founding of the Royal Society in London in 1662, which had the imprimatur of King Charles II. It would become the model for scientific societies throughout Europe in the next generation. Newton's career would parallel the rise of the Royal Society: he sent his earliest papers, on optics, to the Society for publication in its *Philosophical Transactions* in the 1670s; published his magnum opus, *Philosophiae Naturalis Principia Mathematica* (Mathematical Principles of Natural Philosophy) through the Society in 1687; and would eventually become its president in 1703. By the time of Newton's death in 1727, England and its political and intellectual life were fundamentally different than they were at the time of his youth, and Newton played as central a role in transforming the intellectual and cultural life of his country as any other figure. Although he is usually mentioned along with Robert Boyle and Charles Darwin as one of England's three greatest scientists, he might also be listed along with Milton and Shakespeare, for his impact on British intellectual life in the early modern period was deep and lasting. Scientists, philosophers, mathematicians and even theologians spent much of the eighteenth century digesting, furthering, and criticizing Newton's work. He played the kind of role that Kant played in nineteenth-century German-speaking philosophy: everyone worked in his wake.

Isaac Newton himself lived a somewhat tumultuous life. The tumult resulted from early tragedies in his family: his father died a few months before he was born and he spent much of his childhood away from his mother. Contradictions emerged later: an intensely private person who shunned public controversies from his earliest days, he was also a recognized public intellectual, a knight of the British Empire who not only presided over the Royal

Society but also sought a seat in Parliament (representing Cambridge) and served in London in the politically influential post of Warden of the Mint. A founder of what we now call modern mathematical physics, he was also a deeply religious man with numerous—often deeply heterodox—opinions on biblical chronology, the history of Christianity, and theological doctrine, including the nature and status of the Trinity.[1] Although anti-Trinitarianism was illegal due to the Blasphemy Act of 1648, Newton embraced it privately, providing hints to friends like the philosopher John Locke in the early 1690s and the philosopher–theologian Samuel Clarke in his later years. He agonized over finding the proper interpretation of scripture and of Christianity's most complex doctrines. Newton's *Nachlass*[2] includes not only hundreds of pages of work in mathematics, optics, and natural philosophy but also numerous manuscripts dealing with alchemical experiments and the history of alchemical thought and thousands of pages of theological materials from every decade of Newton's life[3]: a complex man, indeed.

Newton's immense impact on science and society, and his immensely complicated personality, transcends the capacity of any one volume to capture it. Blackwell Great Minds is devoted to the history of philosophy. If we employ the history of early modern philosophy as the lens through which to view Newton's work, what picture emerges? Newton was not a systematic philosopher: although he read a number of systematic philosophical treatises, including Descartes's *Meditations*, he never wrote one. But he did in fact develop and defend a wide range of philosophical views. He did so primarily in reaction to the many controversies that his publications, ideas, and methods generated from his earliest work in the 1670s until the end of his life in the first third of the eighteenth century. Hence, the focus in this book is on Newton's philosophical debates and discussions with other thinkers—including, especially, Descartes and his followers, Huygens, Locke, and finally Leibniz and his followers. The philosophically salient aspects of Newton's life can be broken into three stages for simplicity's sake: the early years, circa 1660–1680; the middle period, circa 1680–1700; and the late years, 1700–1727. Each of these periods involved substantial philosophical output in reaction to substantive debates.

The early period took place largely in Cambridge. After finishing his studies as an undergraduate at Trinity College, Cambridge in 1665, Newton did considerable work in mathematics (and other areas), rising to become the second Lucasian Professor of Mathematics at the University of Cambridge in 1669 (the first holder of the chair was his teacher, Isaac Barrow). His required course of lectures as Lucasian Professor includes some important reflections on mathematics and natural philosophy. During the 1670s, he also made lasting contributions to experimental optics that helped solidify his reputation in England and abroad. The debates about methodology prompted by his optical writings prefigured an important aspect of Newton's lifelong philosophical work, especially the issue of whether *hypotheses* or other kinds of speculation should be embraced in philosophy.

In the middle period, the 1680s–1690s, Newton made huge advances in natural philosophy, culminating in the publication of his magnum opus, *Principia Mathematica*, in 1687. During this period, Newton befriended John Locke and had several important philosophical exchanges with various figures, including G.W. Leibniz (the German philosopher and mathematician) and Richard Bentley (a London theologian and later the long-serving Master of Trinity College). By the turn of the new century, *Newtonianism* was a powerful intellectual force in England and was soon to be one on the Continent. But it remained highly controversial.

The final period of Newton's life was focused on developing his philosophy and on defending it against its numerous critics. The most dramatic moment in this period came in 1715, when Leibniz articulated several powerful philosophical objections to Newtonianism in a series of letters sent to Princess Caroline of Wales and through her to Samuel Clarke (who was then a member of Newton's circle in London). This ignited a major cross-Channel debate that precipitated the Leibniz–Clarke correspondence, perhaps the most influential philosophical exchange of the entire eighteenth century. Controversy did not subside with Newton's death: in the following decades, the Leibnizian and Newtonian systems had displaced Cartesianism as the major philosophical orientations of Europe and the debate between them continued throughout the rest of the century. Émilie du Châtelet wrote an important treatise, *Institutions de Physique* (1740), which attempted to mediate the dispute between Leibniz and Newton, and in his *Critique of Pure Reason* (1781), Immanuel Kant continued that general project with his groundbreaking work. The shadow of Isaac Newton was long indeed.

1.1 Background and Childhood

In a small town in Lincolnshire, England, Hannah Newton gave birth to her son Isaac early on Christmas morning in 1642.[4] The fact that he was born on Christmas obviously became the stuff of legend. Isaac was apparently in a very weak condition when he was born—it took a full week before he was baptized, on the first day of the New Year. Although he would eventually rise to become the world's greatest natural philosopher, his early years were marked by tragedy. Isaac's father and namesake had died while Hannah was 6 months pregnant, so the two never met. What kind of effect this fact had on Newton's upbringing has been the subject of intense speculation over the years.[5] It may have helped shape Isaac's lifelong inability to maintain friendships he had formed. Luckily for Hannah and the young Isaac, his father left a modest estate including a manor house and a flock of roughly 200 sheep, which was above average for this part of the English countryside. The Newtons therefore were far from wealthy, and were certainly not aristocracy, but the family was in a stable financial position during Isaac's youth. This stability, however, was soon torn by another event: when he was just 3, his mother, Hannah, remarried and left him in the care of his maternal grandmother. He would not live with his mother again until he was 11, so his formative years were spent without either of his parents. Nonetheless, Hannah was a resourceful person, for her second marriage, to the Reverend Barnabas Smith, greatly increased the family's wealth and helped to secure Isaac's future. We can only speculate about the challenge she faced in helping her family at the cost of living apart from her young son. For his part, the elder Newton recalled feeling great anger during his youth.

Despite Hannah's finances, it seems that few in her family had received any formal education. Indeed, it appears that Isaac's father could not write his own name.[6] But things would be different for the young Isaac. His mother arranged for him to attend the Grantham School, where the influential Cambridge Platonist Henry More had also gone as a boy (one of Newton's teachers was More's former student). He enrolled at age 12 and lived with the nearby apothecary—he thus lived apart from his mother again after just a year together. He presumably studied mostly Latin and almost certainly no mathematics at Grantham, and he would have devoted substantial time to Bible study. Although he learned no mathematics and no natural philosophy at this time, both of which were flourishing in England and on the Continent in this period, his knowledge of Latin and of scripture would serve him throughout the rest of his life. More immediately, they also prepared him for future university study. But he would not continue with his studies directly: when he graduated from Grantham at 17, his mother called him back to Woolsthorpe and tried to encourage him to engage with the upkeep of the family farm. Apparently, these efforts came to naught. Isaac was ill suited to farm life and did little to help with the daily work on his mother's land. Her small staff thought he was useless; one of them noted that he was fit "for nothing but the 'Versity.'" That turned out to be a prescient remark: in June 1660, when he was not yet 18, Isaac would set out on a journey for Cambridge. In a sense, he would never return.

On June 5, 1660, the young Isaac passed his entrance examination and enrolled in Trinity College. The colleges were technically separate from the University of Cambridge: students who sought degrees would enroll in the university as well. Newton did so 1 month after arriving in Cambridge. Although he had traveled just over a 100 kilometers, he had obviously entered a completely new world. The son of functionally illiterate parents, he was now a full-fledged member of one of the oldest institutions of learning in all of Europe.[7] He would eventually become one of its most famous graduates.

1.2 Early Years in Cambridge

The university as an institution had existed in England since the twelfth century, and in Newton's day, the curriculum at Cambridge's colleges had not changed substantially in many years. Indeed, it seems that much of the formal study at Trinity College—in fields such as logic, ethics, and rhetoric—had little influence on Newton's thinking and on his future work. But the curriculum was just one aspect of the flourishing intellectual community that the young Newton had joined, and it is this wider community that enables us to understand how Newton received his true education. There are two crucial features of the community that profoundly influenced Newton in his first years in Cambridge. First, he began to learn substantial amounts of mathematics, both through his own reading of texts like Euclid's *Elements* and van Schooten's extended Latin edition of Descartes's *Geometry* and especially through the instruction of Isaac Barrow, a Cambridge don who was the first person to hold the now famed Lucasian Professorship of Mathematics. Newton attended Barrow's lectures on mathematics and worked with him personally. It was Barrow more than any other figure at Cambridge who came to recognize Newton's intellectual gifts, not to say his genius, and who quickly facilitated his rapid rise at Trinity College. Given that the 17-year-old Newton knew little if any mathematics after his training at Grantham, it is astonishing that he would become the second holder of the Lucasian chair a mere 9 years after arriving in Cambridge, discovering the generalization of the binomial theorem and fundamental aspects of what we now call the integral and differential calculus in the intervening period. Such facts present us with the temptation to picture Newton as a lone genius, finding and solving complex mathematical and scientific problems completely on his own through sheer intelligence. Despite his undeniable and prodigious gifts, the young Newton did not exist in an intellectual vacuum: if it were not for Barrow's instruction and encouragement, we do not know what Newton might have accomplished on his own. Second, and just as importantly, although the curriculum was of little use to Newton, like many enterprising and talented young students, he was instructed to read the great *moderns* on his own. His notebook from his early years at Trinity College records his voluminous reading of More, Galileo, Descartes, Charleton (who passed on the views of Gassendi and of certain atomists), Hobbes, and Boyle, among others (McGuire and Tamny 1983). Because of these two facts, Newton quickly became aware of the very latest and most advanced work in both mathematics and natural philosophy. It would not be long before he himself had made major advancements in each of these areas.

Newton's early years are now the stuff of legend. As with many legends, some details are apparently apocryphal, but there may be a kernel of truth in them. For instance, during the great plague of the summer of 1665, Newton returned home to Woolsthorpe to stay with his mother, as Cambridge was evacuated. During his stay in the countryside, the famed episode of the falling apple is said to have happened. The story is compelling and fits with our conception of the lone genius grappling with a nearly unsolvable problem, like the question of how to understand free fall on earth and the motions of the planetary bodies in a unified way. But it simply is not true that Newton discovered his complete theory of universal gravity at this time: we can document the emergence of that theory during the period from 1684 to 1686, the time when Newton wrote successive drafts of a manuscript entitled *De motu corporum* (On the motion of bodies). This ultimately became *Principia Mathematica* (1687, first edition), but only after many drafts and many crucial developments. It also seems that Newton had not yet conceived of his crucial concept of impressed force (*vis impressa*), which sits at the center of his mature physics (Westfall 1980, 148). But 1664–1666 has been called Newton's *anni mirabiles*, or miracle years, for a good reason: he did make substantial advances in mathematics at this time; in particular, he claimed years later that he had worked out his fundamental conception of the calculus during these 2 years. This is obviously a remarkable feat for a young man who had just a few years of college under his belt, having had a rather paltry education before then, especially in the relevant areas. When Newton returned to Cambridge in 1667, Isaac Barrow eventually learned of these great leaps in mathematics and was wise to promote Newton to the Lucasian chair a mere 2 years later. Perhaps no embellished legend is needed: it is astonishing to think that basic aspects of the calculus—which remains so fundamental to modern science and mathematics to this day—were worked out by a young college student on a farm in the English countryside.[8]

Another legend of Newton's early years is that he worked in an intellectual vacuum, holed up for hours at his mother's house or in his room at Trinity College, a solitary figure single-handedly discovering many fundamental underpinnings of modern mathematical physics. The kernel of truth here, of course, is that Newton did in fact grow up largely on his own—at least without his parents—and his 2 years in Woolsthorpe during the plague were spent largely alone, at least intellectually speaking. His achievements during those years are obviously awesome by any measure. But as we have seen, Newton was not alone in Cambridge: he had the important influence of senior figures and his records from the time record celebrations with friends in the tavern when he received welcome academic news. So the legend must be tempered.

Newton's actual writings during his early years as Lucasian Professor indicate a prodigious output. In the period 1670–1675, Newton created a telescope, celebrated by the newly formed Royal Society, and made fundamental contributions to optics, which were published in the *Philosophical Transactions* (see Chapter 3). As it turned out, Newton's claim that he had used a prism in order to determine experimentally that ordinary sunlight contains a series of embedded rays of various colors and that the colors of the rainbow are not created through a modification of light embroiled him in a substantial controversy. Numerous important figures from this time, including the famous Continental mathematician Huygens and the London experimental philosopher Robert Hooke, objected to Newton's methodology. Newton found the ensuing extensive debate extremely taxing, and he developed a lifelong aversion to intellectual controversy. But his reputation, both in England and, increasingly, on the Continent, had been established. It was soon to increase dramatically.

1.3 Mature Years in Cambridge and London

Despite these early achievements, no one among Newton's contemporaries was prepared for his work in the next decade. In this period, the stuff of legend is not apocryphal: it is well documented. As has been told countless times, in August of 1684, Edmond Halley—for whom Halley's 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 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 a circle.[9] 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*, 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*. It is shocking to think that if Halley had not visited Newton and then persisted in talking with him, one of the founding texts of what we now call modern science might not exist.[10]

While he was writing the text that was to become the *Principia*, Newton corresponded with Halley. One of his letters in particular indicates how Newton understood the discipline of natural philosophy, to which he intended to contribute with his new book, even while warning Halley of his aversion to intellectual debate. On June 20, 1686, he wrote to Halley as follows:

> I designed the whole to consist of three books.... The third I now design to suppress. Philosophy is such an impertinently litigious lady that a man had as good be engaged in law suits as have to do with her. I found it so formerly [he presumably means the 1670s optics disputes] & now I no sooner come near her again but she gives me warning. The two first books without the third will not so well bear the title of Philosophiae naturalis Principia Mathematica & therefore I had altered it to this De Motu corporum libri duo: but upon second thoughts I retain the former title. Twill help the sale of the book which I ought not to diminish now tis yours. (Correspondence II: 437)

This letter was sent in response to Halley, who had written to Newton 2 weeks earlier that he ought to include Book III because "the application of this mathematical part, to the system of the world; is what will render it acceptable to all naturalists, as well as mathematicians, and much advance the sale of the book" (*Correspondence* II: 434). Without the third book, in which Newton discusses what he calls "the system of the world," the first two books of *Principia Mathematica* could not very accurately be called natural philosophy; rather, they would be better described as "two books on the motion of bodies." For Newton, as for Halley, natural philosophy was not principally concerned with just any motion of bodies that was tractable through mathematical analysis; rather, it was concerned with the mathematical analysis of the actual motions of the bodies within our solar system—within nature as we perceive it in our vicinity of the universe. That coheres with a long tradition in natural philosophy. Newton's innovation is to provide a mathematical analysis of the motions of these bodies (Chapter 5 describes why this maneuver is innovative). It is no surprise that for Newton, as for many natural philosophers in this period, one of the great outstanding questions is how to understand the earth–sun system, including the question of whether the earth or the sun is at its center. Just a year after this letter, the first edition of what many would now regard as the first true text of modern mathematical physics appeared. For his part, Halley wrote an anonymous piece in the *Philosophical Transactions* announcing the arrival of the text: "it may be justly said, that so many and so Valuable *Philosophical Truths*, as are herein discovered and put past Dispute, were never yet owing to the Capacity and Industry of any one Man."[11] And so at the age of 44, Newton was quickly propelled into the first rank of mathematicians and philosophers in England.[12]

The decade of the 1690s brought Newton considerable attention for his magnum opus, along with several new and significant friendships. When John Locke returned from political exile in 1688, he made a point of meeting Newton soon after and the two struck up a friendship. Their correspondence indicates that they held similar unorthodox religious beliefs, each finding reason, for instance, to question the official Anglican doctrine of the Trinity. These beliefs were closely held by Newton throughout his adult life, and Locke may have been the first person to whom he revealed them. In the second edition of the *Principia* in 1713, Newton may have given some hints as to his real views, especially in the newly added General Scholium at the book's end, but he would never publish his anti-Trinitarian conceptions openly, as they would have landed him in considerable political (and perhaps legal) trouble. For his part, Locke took Newton's work very seriously: he wrote an anonymous, largely laudatory, review of the *Principia* (having famously asked Huygens to vouch for the mathematics he could not understand) in the *Bibliothèque Universelle*, mentioned Newton in the preface to his *Essay Concerning Human Understanding* (1690), and told Bishop Edward Stillingfleet that Newton's work had convinced him that his long-held mechanist understanding of natural change required revision (see Chapters 5 and 6).

During this same time, Newton quickly developed an intense and very close friendship with the Swiss mathematician Nicolas Fatio de Duillier, who reports being converted from Cartesianism to Newtonianism in the process (Westfall 1980, 493). Yet Newton's tumultuous personal life did not come to an end with these particular friendships: as his correspondence amply demonstrates, he often found himself passionately devoted to a friend, only to have a significant fight with him later. Some scholars have speculated that the constant tumult of Newton's life can be traced back to the absences of his childhood.

In the mid-1690s, the allure of Cambridge and its intellectual environment had begun to fade for Newton. The figures who had such an immense impact on his early years, especially Isaac Barrow and Henry More, had long since died, and in some ways, the intellectual life that Newton sought had shifted to London, where figures like Richard Bentley were then living, and where the Royal Society was located.[13] But Newton did not move to London merely to seek intellectual company, and the picture of Newton as the solitary scholar is difficult to square with his many years in the capital. In 1696, after 35 years in Cambridge, Newton decided to move permanently to London, taking up the post of Warden of the Mint as his new official position. Newton's time as Warden, focused on bureaucratic and logistical issues, especially the question of how to defeat counterfeiters of the currency, is of little interest philosophically, but it does indicate that the mature Newton was a political figure and far from being a solitary scholar. Newton's political position, however, did not end his philosophizing: it was during this period that he finally decided to publish what became his second great book, the *Opticks*. Newton's research in optics was largely in completed form long before he decided to publish his work, and the results of his numerous experiments, together in a single volume. In 1704, the first edition of the *Opticks*, which would lead to its own powerful tradition in the experimental aspects of natural philosophy in the eighteenth century, appeared after the death of Newton's old rival in optics, Robert Hooke. Newton's friend, Samuel Clarke, translated the *Opticks* into Latin in 1706, thereby making it available to a wide Continental audience. In subsequent editions, Newton would add a series of long *Queries* as appendices to the volume: these sections of the text, which presented some of Newton's more speculative views in natural philosophy, early chemistry, and even theology, would have a long afterlife. With Newton's two texts, he had made fundamental contributions to both the mathematical and the experimental sides of the program in natural philosophy that would forever be associated with his name.

Warden of the Mint was not Newton's most important official position during this period of his life. In 1703, the Royal Society elected him its President, a role for which he would forever be known, and he threw himself into its activities. The society, which had foundered for some time during the previous decade, began to flourish again under Newton's leadership. Some of the talents for administrative duties and details that he had shown during his time as Warden became evident when he was President. Newton was soon to reach the pinnacle of his political and institutional power: 2 years after becoming President, Queen Anne knighted him in a grand ceremony back in Cambridge. He would thereafter be known as Sir Isaac.

1.4 Final Years

Although Newton did not publish another major work during his last two decades, he did make substantial revisions and additions to both the *Opticks* and the *Principia*. Many of these changes were prompted by the serious criticisms leveled against his views by leading mathematicians and philosophers on the Continent, especially Huygens and Leibniz. Indeed, the last two decades of Newton's life are marked by an intriguing contrast: on the one hand, Newton was at the height of his intellectual and institutional power and prominence, and he held an unquestioned position as the leading intellectual figure in England at that time; on the other hand, despite his numerous followers throughout his native land, including Bentley and Clarke, his views in natural philosophy and in theology (to the extent that they were known) were the subject of vigorous debate and deep controversy throughout the Continent. Numerous figures in Europe in the early eighteenth century were still convinced of the basic truth of Cartesianism, and therefore spent considerable energy attempting to undermine Newton's views. For those who had come to dispense with Cartesian ideas, however, there remained a powerful and influential alternative to Newton, namely, the philosophical orientation of Leibniz (Chapter 6). In the 1690s, Leibniz had published a number of important papers—in the *Acta Eruditorum* and elsewhere—that were critical of Descartes's views in natural philosophy and metaphysics, and many figures in the early eighteenth century saw him as the leading metaphysician of the day.[14] An extensive debate between Leibniz and his followers and Newton and his followers would erupt during this period, focused both on substantive philosophical, theological, and mathematical issues and on nonsubstantive issues connected with the political and nationalist implications of the calculus priority dispute. The many denunciations issued by both sides in the dispute over which mathematician first discovered the calculus, which became extremely heated in the 1710s and ended only with Leibniz's death in 1716, should not overshadow the genuine and genuinely interesting philosophical issues debated by both sides.

Leibniz and Newton had briefly and cordially corresponded with one another in 1693 (Newton 2014, 141–145). Although brief, we do see a glimmer of their future disagreement concerning the best understanding of gravity: Leibniz insisted that the action of gravity, both terrestrially and celestially, be reduced to contact action in some fashion, perhaps owing to interactions with a fluid vortex in the heavens, but Newton resisted this maneuver (Chapter 6).

They would never agree on this issue, and as the calculus priority dispute heated up in the beginning of the next century, their philosophical differences deepened. In 1711 and 1712, Leibniz made it known to various correspondents and colleagues that he remained unconvinced by Newton's theory of gravity, especially its deviation from the norms for causal explanation established by the so-called mechanical philosophy. He also fundamentally rejected the conception of space, time, and motion that Newton articulated in the famous opening Scholium of the *Principia*, contending that it violated the principle of sufficient reason, which Leibniz took to be a bedrock principle with which every physical theory must cohere. When Newton was revising the *Principia* in 1713 with the help of the new general editor, Roger Cotes, a fellow of Trinity College and himself a promising young philosopher, he certainly had his eye on these disputes with the Leibnizians. Hence, the second edition of the text contained numerous remarks—in various parts of the main text, in Cotes's long editor's preface, and in the new final appendix, the General Scholium—concerning the methods of Newton's philosophy designed to rebut the criticisms of Leibniz and others.

Yet this debate did not subside with the new edition of the text. In 1715, Leibniz sent a scathing criticism of Newtonian ideas to one of the most prominent political figures in England at the time, Princess Caroline of Wales. Her role as a mediator, and perhaps instigator, of a broad philosophical debate between the two camps was crucial (Bertoloni Meli 1999, 2002). She ensured that the circle around Newton saw the letter, and it was decided that the theologian Samuel Clarke, a close friend of Newton's at this time and his parish priest in London, would reply to Leibniz on Sir Isaac's behalf. Although Newton had corresponded with Leibniz before, his well-known and nearly lifelong aversion to controversy may have led him to choose Clarke instead of responding himself. In addition, Leibniz raised theological and metaphysical objections against Newtonianism in his first letter to Princess Caroline, and since Newton had never developed a systematic philosophical conception of the world, as Clarke had done in his *Demonstration of the Being and Attributes of God* (1704), it was wise to choose a systematic philosopher and theologian like Clarke to reply to Leibniz's charges. What ensued was an extensive, increasingly detailed, and increasingly acrimonious, but nonetheless substantive, philosophical debate that touched on all the major topics of the day: the nature of space and time, the proper method of natural philosophy, the uses of experiment, the nature of miracles, and God's relationship to the creation, including the possible inscrutability of the divine will. The correspondence was hugely influential throughout the eighteenth century. In France, led by figures like Émilie du Châtelet, and in German-speaking Prussia, led by Immanuel Kant, the debate between the Leibnizians and the Newtonians became the centerpiece of much work in theoretical philosophy and metaphysics.[15] Descartes had been decisively eclipsed by his two greatest critics of the late seventeenth century.

Despite his frailty at birth, Newton outlived Leibniz and many of his other critics and friends.[16] He spent the last years of his life in declining health. A third edition of the *Principia* appeared in 1726, just a year before he died, but it did not differ substantially from the second edition.[17] And as might be natural, Newton spent his last few years reminiscing about his past and telling stories to his friends and acquaintances. It is apparently from these days that the story of the apple originated (Westfall 1980, 862). Despite his declining health, however, Newton continued to preside over the Royal Society. And the Society's influence continued to be felt: on Newton's last meeting, in March of 1727, a letter from the newly formed Academy of Science in St. Petersburg was read. Just 3 weeks later, Sir Isaac died at the age of 85. The Royal Society canceled its next meeting in the wake of his death. By the end of that month, he had been interred in Westminster Abbey, at the center of London and indeed of British politics and culture, where his crypt remains to this day.

Newton's ideas did not die with him. His most profound impact on the future was probably the orientation toward solving problems outlined in the *Principia*. Although he chose to employ complex geometrical methods and future work would be done in the language of the calculus (which of course Newton himself discovered), there is no doubt that it is accurate to call the physics of the late eighteenth and early nineteenth century *Newtonian*.[18] Just as profoundly, although Einstein's revolutionary work in 1905–1915 helped to establish a new orientation toward physics with the special and general theories of relativity, it remains the case that even from the new perspective, Newton's theory is *approximately* true. Engineers still use Newtonian ideas to this day. This means that Newton made a lasting contribution to our understanding of the natural world. He also had a profound impact on the subsequent history of philosophy. For many philosophers—one might mention a crowd as diverse as John Locke and David Hume in England, Émilie du Châtelet and Voltaire in France, and Immanuel Kant in Prussia—Newton's science could be understood as replacing geometry as a fundamental epistemological model for knowledge-seeking endeavors. It could also be seen as providing a picture of the natural world, and of the laws that govern it, that any philosophically serious perspective must confront. It is no exaggeration to say that the main philosophical debates, projects, and preoccupations of the eighteenth century can be understood only in the light of Newton's work and influence.

notes

1 There are numerous biographies of Newton stretching back for roughly two centuries, along with various fictionalized accounts of his life and work. The most comprehensive account remains the classic biography (Westfall 1980).

2 In the early modern period, it was common for correspondence between two individuals, and the unpublished manuscripts of one author, to circulate among various intellectual circles. Hence, I include correspondence and some of Newton's manuscripts to be part of the canon of the *public Newton*. For instance, manuscripts such as *De Gravitatione* and the famous *De Motu* drafts from 1685, which connect very closely with Newton's published work in the *Principia* and his correspondence with various individuals, would count as part of this canon. As we will see, there is also evidence that John Locke knew about the ideas of *De Gravitatione*, if not the text itself. But his manuscripts in alchemy and biblical chronology are not continuous with any published works and therefore have a more private status. This is of course a rough methodological distinction that bears further thought.

3 Betty Jo Teeter Dobbs did foundational scholarship on Newton's work in the alchemical tradition—see especially Dobbs (1975, 1991). For a discussion of more recent work, see Figala (2002) and William Newman's extensive research, which is represented at "The Chymistry of Isaac Newton" (http://webapp1.dlib.indiana.edu/newton/).

4 Throughout this text, I use the dates of the new calendar, unless otherwise noted (as in this case). For perhaps obvious reasons, it was important to Newton later in his life that his birthday be expressed using the old calendar, since he was born on Christmas by it (not to mention the year of Galileo's death) but in 1643 by the new calendar in use on the Continent.

5 See especially the influential and controversial account in Manuel (1968).

6 Hannah Newton seems to have been semiliterate: there is apparently a single surviving letter from Hannah to her son; in it, she expressed her love for him and indicates that she prays to God for him. It was sent in May of 1665, after Newton had been in Cambridge for 5 years, but the original is torn and therefore incomplete (see Westfall 1980, 141)

7 The University of Cambridge was founded in the early thirteenth century—legend has it that the university was founded by intellectuals who had grown weary of the new university in Oxford. Henry the VIII founded Trinity College in 1546.

8 It is now accepted that G.W. Leibniz developed his own version of the calculus independently of Newton. The debate over the calculus priority dispute raged ferociously among Newton and Leibniz's circles in the early eighteenth century, but historians put little stock in the debate today. See especially Hall (1980) and Bertoloni Meli (1993).

9 Although astronomers for centuries had thought that the planetary orbits must be circular, for various important reasons, 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 figure does not constitute a single radius that is equal to all other radii. For that reason, astronomers in antiquity may have considered them less than perfect.

10 On Halley's role in printing the *Principia*, see Cohen (1971, 130–142).

11 See *Philosophical Transactions* 16 (1686–1687): 291–297.

12 This fact does not mean that Newton's contemporaries endorsed his new ideas and methods; rather, even his fiercest critics, such as Leibniz and Huygens, quickly recognized his genius and stated so publically.

13 Bentley was an important theologian. He had been chosen to deliver the first Boyle Lectures in London in 1692; the lecture series was endowed by Robert Boyle in his will for the promotion of reasonable interpretations of Christianity and the establishment of harmony between religion and natural philosophy. Bentley corresponded with Newton in 1693 to seek his advice concerning the religious implications of his *Principia*, and for some time, Newton thought that Bentley might edit the second edition of the text (as it turned out, however, it would be many more years before the second edition was published, under the editorship of the young astronomer Roger Cotes).

14 This was certainly the case in many areas of the Continent, although (for obvious reasons) it took longer for Leibniz's views to be accepted in French regions, where Cartesianism continued to flourish for the first few decades of the eighteenth century. However, by the 1730s and 1740s, it had come under significant attack by figures like Voltaire, who wrote extensively about the superiority of Newton's views, and by figures like Émilie du Châtelet, who argued that the views of Leibniz—and of his prolific follower Christian Wolff—were superior to those of Descartes. Indeed, for influential figures like Châtelet, even more so than for Voltaire, the great philosophical struggle of the eighteenth century would be between Leibnizian and Newtonian ideas.

15 Émilie du Châtelet's work, *Institutions de physique*, first published in Paris in 1740 and again in revised edition in Amsterdam in 1742, attempted to mediate the dispute between the two camps by establishing a Leibnizian metaphysical foundation for Newtonian physics. Although it was immediately translated into German and Italian and had a major influence on French Enlightenment thought, the *Institutions* was never translated into English and has unfortunately been ignored by many histories of eighteenth-century philosophy. Intriguingly, working in Prussia a generation later, Immanuel Kant (who cited some of Châtelet's work) also determined that his fundamental problem was to reconcile the leading (Leibnizian) metaphysics of his day with the leading (Newtonian) physics. This problem animated both his so-called precritical work and also the *Critique of Pure Reason* (1781). On Châtelet, see Hutton (2004) and Detlefsen (2013); on Kant, see especially Friedman (1992, 2012).

16 Leibniz died in November of 1716, which abruptly ended his correspondence with Clarke. Although Clarke himself outlived Newton by 2 years, others in Newton's circle died earlier, including John Locke (who died in 1704) and Roger Cotes (who died very young in 1716—he was just 5 years old when the first edition of the *Principia* appeared). Although he was not sentimental, Newton did mourn the loss of these friends: in the case of Cotes, he was reported to have said, with typical understatement, "if Cotes had lived, we may have learned something."

17 Philosophically speaking, one of the most important additions was the new Rule Four in the *Regulae philosophandi* section of Book 3.

18 By the end of the century, the various disputes among Cartesians, Leibnizians, and Newtonians had died out, at least as far as physics itself was concerned. This reflects, in part, the fact that physics was becoming separated from philosophy; or more accurately, it reflects the fact that the natural philosophy practiced by figures like Descartes and even Newton was separating into two distinct fields, as I discuss in Chapter 2. For a detailed and illuminating account of Newton's influence on physics as a discipline, see Smith (2012).