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INTRODUCTION

In 1987, the year in which the tercentenary of the publication of the *Principia* was celebrated, D.T. Whiteside, the indefatigable editor of Newton's mathematical papers, wrote that there existed "a broad balance of agreement over the main stages" in the evolution of Newton's masterpiece, and that scholars were "no longer set greatly awry by the nuggets of *Principia* gold still (if with decreasing frequency and size) to be sieved from Newton's papers by those willing laboriously to do the panning."[1] Over the ensuing decades, discerning scholars have indeed unearthed not a few nuggets. However, the *Principia*'s stark light has understandably tended to overshadow the life and work of the young Newton. We shall see that he only occasionally grappled with issues concerning motion during the two decades prior to the treatise's publication. Moreover, Newton formulated what would become the law of universal gravitation only late in the process of composing his treatise. Throughout the 1670s, for example, he was principally occupied with *chymistry*, as the manipulation of substances to produce novel amalgams was then known.[2]

The present book accordingly offers a new delineation of the wandering path that Newton traversed. To that end we have aimed to examine and evaluate his readings and discoveries within their specific contexts, giving due weight to the influence of mentors and colleagues whose input helped shape the eventual masterpiece, working, to the extent possible, without reference to the published *Principia*.

We explore how Newton's engagement with motion evolved *seriatim* as he read, studied, and engaged with books and colleagues at Trinity College, Cambridge, and beyond. Motion did attract his attention early on. It did so however in ways that were averse to exploring the nature of space, time, or even matter proper, for Newton worked, as did Isaac Barrow, with a spare vision of space:

1 D. T. Whiteside, "The Prehistory of the *Principia* from 1664 to 1686," *Notes and Records of the Royal Society of London* 45 (1991): 11.

2 William R. Newman, *Newton the Alchemist: Science, Nature's Enigma, and the "Secret Fire"* (Princeton, 2019).

a container populated by geometrically governed objects. We will see that the occasional remark during these years concerning the underpinnings of such matters was generally prompted by his perceived need to avert potential criticism. Whenever Newton's attention turned to issues of motion, he drove rapidly to the construction of a system grounded on a set of presumptive interactions between bodies. These had unchanging identities, which provided the essential foundation for him to generate computational structures tied, we shall see, to measurement. As Levitin summarized, Newton's scientific endeavors had always been "confined to knowledge of the phenomenological properties of things," not to a search after causes. Only such knowledge, he was convinced, could yield certainty.[3] In so doing, Newton embraced, and extended, Isaac Barrow's advocacy for generating physical explanation "after the mode of mathematicians."[4] There is no part of physics, Barrow insisted in 1664, "which does not Imply Quantity, or to which geometrical Theorems may not be applied, and consequently which is not some Way dependant on Geometry."[5] Newton concurred. In his third lecture on optics, delivered in January 1669/70, he sought to establish "how valuable mathematics is in natural philosophy" and to "urge geometers to investigate nature more rigorously, and those devoted to natural science to learn geometry first"—so that "with the help of philosophical geometers and geometrical philosophers, instead of the conjectures and probabilities that are being blazoned about everywhere, we shall finally achieve a natural science supported by the greatest evidence."[6]

Two and a half years later, when defending his theory of the unequal refrangibility of light against Robert Hooke's criticism, Newton titled the final section of his lengthy retort: "That the Science of Colours is most properly a Mathematicall Science." Not only did Newton vigorously defend, in the fashion of Barrow, "the certainty of Mathematical Demonstrations" in optics—and in the physical sciences more generally—but he instantiated his mentor's opinion concerning the

3 Dmitri Levitin, *The Kingdom of Darkness: Bayle, Newton, and the Emancipation of the European Mind from Philosophy* (Cambridge, UK, 2022), 510–12.

4 CUL MS Add. 3970, fol. 433^{v}; Alan E. Shapiro, *Fits, Passions, and Paroxysms: Physics, Method, and Chemistry and Newton's Theories of Colored Bodies and Fits of Easy Reflection* (Cambridge, UK, 1993), 23 and 23n34.

5 Isaac Barrow, *The Usefulness of Mathematical Learning Explained and Demonstrated: Being Mathematical Lectures Read in the Publick Schools at the University of Cambridge*, trans. John Kirkby (London, 1734), 22.

6 Isaac Newton, *The Optical Papers of Isaac Newton*, ed. Alan E. Shapiro, vol. I, *The Optical Lectures 1670–1672* (Cambridge, UK, 1984), 87–89.

status of experiments in the realm of physico-mathematics. The confirmation of many propositions by "frequent experiments," Barrow stated, assured us of the constancy of nature, and from this constancy "we may prudently infer an universal Proposition even by one Experiment alone."[7] Newton did just this in the *experimentum crucis*: a meticulously designed single experiment which yielded the anticipated result. As Newton clarified in the draft version of his defense, ever since he had become acquainted with the mathematical principles of the science of colors, he met "<wth constant sucesse in ye events> [and] made use of them for this purpose ~~& always found the events answerable to my predictions~~."[8] Newton's kinematic conception of the generation of curves by motion was also indebted to Barrow, and he endorsed his mentor's conviction that "the definition of curves in terms of their generating motions satisfied traditional demands for causal arguments."[9]

We shall delineate Barrow's influence as we trace the evolution of Newton's mathematics and his particular way to work with incremental motion changes—one that underpinned at a fundamental level his occasional excursions into such matters during the decades before 1686. In each case we will see that Newton sought always to focus on deploying—and not going beyond—the mathematical tools that seemed apposite to the specific problem at hand. Those tools, which meld with his evolving mathematics, were central to his work on motion. We will see, for example, how even such an astute mathematician as John Wallis who, like Newton, could work conceptually with an incremental deconstruction of motion, nevertheless avoided the details of Newton's constructive procedure. Newton sought always to generate a scheme that bound closely to measurement in ways that he intended would brook no counterargument to his claims, and his unique deconstruction of motion facilitated his objective. This amounted to a rigid, stringent requirement on what Newton

7 Barrow, *The Usefulness of Mathematical Learning*, 74. The emphasis on a well-executed single experiment was held by Robert Boyle as well as by Barrow: ". . . experiments ought to be estimated by their value, not their number; and that a single experiment . . . may as well deserve an entire treatise, as a great many less considerable ones. As one of those large and orient pearls, that are fit to adorn a monarch's crown, may outvalue a very great number of those little (though true) pearls that are to be bought by the ounce in goldsmiths and apothecaries shops." Robert Boyle, *The Works of the Honourable Robert Boyle*, ed. Thomas Birch, vol. 1 (London, 1744), 239.

8 CUL MS Add. 3970, fol. 438^{v}; Levitin, *Kingdom of Darkness*, 512–13.

9 Christopher Smeenk, "Philosophical Geometers and Geometrical Philosophers," in *The Language of Nature: Reassessing the Mathematization of Natural Philosophy in the Seventeenth Century*, ed. Geoffrey Gorham et al. (Minneapolis, 2016), 310.

would allow to be a secure assertion—whether in optics, *chymystry*, or motion. Anything less amounted, at best, to speculation. Throughout the book we have placed particular emphasis on what might seem to be minor differences between Newton and some of his contemporaries. Yet here, we argue, lies the true novelty, and power, of Newton's particular ways with mathematics, aimed in the end at measurement. Anything else was undoubtedly of interest to him, but decidedly a side issue that could not sustain the certainty that he demanded even as a young scholar at Cambridge. Perhaps more than anything else, this fervent insistence distinguishes Newton's work from that of other mathematically astute contemporaries such as John Wallis, Christopher Wren, and even Christiaan Huygens.

We begin with Newton's childhood and undergraduate career at Cambridge, following him as he encountered and assimilated contemporary work, mathematics in particular, inspired as he was by, and engaged in close collaboration with, Barrow. We then scrutinize Newton's earliest work in mechanics, identifying concepts and procedures that persisted throughout his sporadic engagement with the subject in subsequent decades. Stimulated by Cambridge colleagues and correspondents, Newton gradually sharpened specific ways to think about, and to work with, mechanical interactions. A 1679 exchange of letters with Hooke proved of the utmost significance. It led Newton to deploy a generalized procedure for constructing a body's trajectory under a given impulsion, a procedure that had originated much earlier in Newton's first efforts to come to grips with collisions. That however engaged his attention only briefly, as did a subsequent exchange about comets with the Royal Astronomer, John Flamsteed. Edmond Halley's visit in summer 1684 prompted a far more focused engagement with such matters, leading in due course to the formulation of the material in Newton's *De motu* manuscripts, which eventually became Book I of the *Principia*. We continue with the problems that emerged as he grappled with the several related issues that appeared during these months, leading to the structure that Newton first discussed in words in a manuscript entitled *Liber Secundus*—subsequently to evolve mathematically into Book II of the *Principia*.[10] We shall not probe further into the months during which the *Principia* took its final shape. Instead, we conclude with what Hooke made

10 Only recently has a translation and commentary on the *Liber Secundus* become available. George E. Smith et al., *The Development of Newton's Principia During 1685* (Cham, 2026).

of these new developments when he gained access to, and carefully studied, Newton's draft *De motu*.

The works of Bernard Cohen, Tom Whiteside, and Sam Westfall opened the way to careful consideration of Newton's work on motion, as well as other areas, including optics. Subsequently, Bruce Brackenridge, Curtis Wilson, Michael Nauenberg, and George E. Smith have carefully explored the mathematical and experimental configuration of critical aspects of Newton's (and his contemporaries') investigations of problems concerning motion. We have relied especially on the last three, with whom we were able to discuss matters over the years. All seven scholars are no longer with us, but we hope that the impacts of their work, and those of others, will become evident in what follows—both in the body of the text and in the notes. We hope to have gone further in providing a new understanding of the manner in which Newton's work on motion evolved, especially as he occasionally came to grips with problems posed to him by interlocutors, and not as a series of concerns that continuously ensnared his attention ever since his arrival in Cambridge. The young Newton we find in the manuscripts was ever seeking a certitude which, he believed, only a mathematics leading to measurement could provide. Remarks that went beyond these parameters, though certainly intended seriously, were engendered principally as he encountered or sought to preclude criticisms or questions that could not attain the kinds of assurance that he always sought. Certainty, whether in mathematics or natural philosophy, was ever Newton's goal.[11]

To gloss anew the scientific background that eventuated in the *Principia* necessitated subjecting the biographical details preserved within the Newtonian *Nachlass* to a nuanced examination. Historians have recognized that Newton's recollections of his youthful endeavors—articulated mostly during the second and third decades of the eighteenth century—were shaped by his determination to assert priority over Leibniz with respect to the origins of the calculus, as well as rebuff Hooke's pretensions with respect to the *Principia*. Newton's statements regarding the sequence and dating of his research were also affected by the cognitive decline Newton experienced in his later years. Henry Pemberton, a close associate in the 1720s, and the editor of the third edition of the *Principia*, addressed contemporary rumors in the preface to that edition. While acknowledging that Newton's "memory was much decayed" in old age, Pemberton insisted that the

11 See Niccolò Guicciardini, *Isaac Newton on Mathematical Certainty and Method* (Cambridge, MA, 2009).

great man had "perfectly understood his own writings, contrary to what [he] had frequently heard in discourse from many people."[12] Conduitt also noted a cognitive decline. Visiting Newton on 7 March 1724/25—following his recovery from "a fit of the gout"—Conduitt found his host's "head clearer & memory stronger than [he] had known him for some time."[13] Cognizant of these factors, we dated the relevant parts of Newton's papers according to our revised understanding of the development of his scientific studies. We have sought to demonstrate that Newton's engagement with natural philosophy and mathematics began somewhat later than traditionally thought. Consequently, we have reassigned dates to various pages and treatises he composed to reflect this revised timeline.

Virtually all our information about Newton's life prior to his appointment as Lucasian Professor of Mathematics in 1669 was collected by John Conduitt—the husband of Newton's niece and the owner of Newton's archive—for a projected biography of his uncle-in-law. Toward that end, in the immediate aftermath of the great man's death in 1727, Conduitt stage-managed the gathering of biographical material to construct a carefully wrought narrative of Newton's early life and work. Despite the problematic nature of the information Conduitt reported, his overall narrative, including its less credible details, has been highly influential. Consequently, deconstructing Conduitt's account is an essential first step for presenting a new intellectual biography of the young Newton, and for a study that seeks to separate his foundational scientific work from results later presented in the *Principia*.

Conduitt's agenda for a biography of his renowned relative clearly molded the nature of the anecdotes he collected from Newton's friends and disciples concerning Newton's childhood and youth and helped shape the image of the young Newton that has long persisted. As we explore in the first two chapters, in the process of seeking information about Newton as a schoolboy, Conduitt and his collaborator, William Stukeley, primed their informants to deliver details signaling early signs of his mature scientific genius. The biographers then imbued these anecdotes with proleptic significance, effectively recasting the young Newton as a natural philosopher *avant la lettre*. As for Newton's career at Cambridge, Conduitt constructed an image of a superior genius who stood apart from his environment. Indeed, Conduitt envisaged a grand narrative modeled on ancient examples, in so doing equating Newton to heroes of old.

12 Henry Pemberton, *A View of Sir Isaac Newton's Philosophy* (London, 1728), a2.
13 Keynes MS 130.11, fol. 1.

He began by paraphrasing Livy's rumination in the preface to *The History of Rome*: whether it be worthwhile to "record the achievements of the Roman people" because "the theme is not only old but hackneyed." Livy responded in the affirmative: "[I]t will be a satisfaction to have done myself as much as lies in me to commemorate the deeds of the foremost people of the world; and if in so vast a company of writers my own reputation should be obscure, my consolation would be the fame and greatness of those whose renown will throw mine into the shade."[14] What was true for Livy, Conduitt glossed, held doubly for himself even though "to compile the life of a private man, spent in speculation . . . afford but little entertainment in the description, & are not so apt to strike a vulgar reader as the tumultuary scenes of pomp & action." But then why shouldn't one find pleasure "in tracing the progress of Reason *in one of our own species*"? To Conduitt, a life such as Newton's, which "*was one continued* series of labour, patience humility temperance, & piety," furnished an example far "more universally beneficial & imitable than the atchievements of a Cesar or the triumphs of an Alexander,"[15] the latter of whom "valued himself more for the little knowledge he had learned from Aristotle than for all his extensive conquests." Indeed, he continued, "Tho^{u} wee should look around the present ages and even go far back into the past, difficult would it be to find an instance of a more exalted Genius & Virtue, of one who penetrated farther into the works of the divine Author of Nature or laid a more solid foundation for a lasting & Universal Empire in Philosophy than S^{r} Isaac Newton."[16] Conduitt placed Newton ahead of "those speculative Conquerors who have extended the limits of humane science & opened new worlds to our understanding." None had penetrated as far as Newton "into the works of the Divine Author of Nature or and laid so solid a foundation for a lasting & universal Empire in Philosophy."[17]

Two components stood at the core of Conduitt's construction. First, he stated repeatedly, Newton had "laid the foundation of all his discoveries before he was 24 years old." Conduitt communicated that claim to Bernard de Fontenelle, perpetual secretary of the French Académie des Sciences, and Fontenelle duly inserted it in his *éloge*: "There are Proofs, that Sir *Isaac Newton*, at 24 Years of Age, had made his great Discoveries in Geometry, and laid the Foundation of

14 Livy, *Ab urbe condita*, trans. B. O. Foster, 14 vols. (Cambridge, MA, and London, 1967), 1:3.
15 Keynes MS 130.2, fols. 1, 3–4; MS 130.3, fols. 1^{r}–2^{v}.
16 Keynes MS 130.3, fols. 1–2^{v}.
17 Keynes MS 130.2, fol. 4.

his two famous Performances, the *Principia* and the *Opticks*."[18] Conduitt appears to have contemplated comparing Newton's accomplishment at 24 years with all that Alexander had achieved by that age, but ultimately settled on a more modest claim: Newton had "laid the foundation of all his discoveries before hee was 24 years old . . . [and subdued] all Nature at an age when even the Cesars in learning were but just beginning their conquests."[19] He undoubtedly had in mind the likes of Kepler and Leibniz, who at age twenty-four had yet to make their great discoveries. Second, Conduitt was intent on persuading his readers that the force of genius alone had allowed Newton to make his great discoveries: "Often the whole life of those who should make new discoveries is spent in learning only what is already found out but Sir Isaac Having read only the few books . . . & without the least help or instruction from any person he laid the foundation of all his discoveries before hee was 24 years old."[20] Such a perspective permeates Conduitt's narrative, echoed again in recollections he solicited from Newton's chamber fellow, John Wickins, as well as from Humphrey Newton, who served as Newton's amanuensis.

In our study, the authenticity of Newton's genius remains unquestioned. Indeed, the evidence pointing to the relatively late start of his scientific pursuits renders the rapid development of his intellect all the more remarkable. Yet, our account moves away from the long-held image of the disengaged scientific genius. Instead, in the first two chapters we present Newton as a gifted—though not exceptionally rare—student of the humanities, who discovered mathematics and the new philosophy shortly before graduating BA, and whose scientific brilliance was nurtured and swiftly recognized by mentors and peers within the distinctive milieu of a particular institution of higher learning.

18 Keynes MS 129.1, fol. 3; MS 129.3, fol. 2^{v}; Bernard le Bovier de Fontenelle, *The Life of Sir Isaac Newton. With an Account of His Writings* (London, 1728), 4–5.

19 Keynes MS 130.4, fol. 14.

20 Keynes MS 130.4, fols. 13–14.

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