

Newton's Scholarship in Historical Perspective*

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In the last half-century, our views concerning Isaac Newton have undergone radical changes. Compared to the past, we have a deeper understanding of Newton's science and mathematics and we have become aware of his full creative stature and the many dimensions of his complex personality. A convenient place to begin our examination of these changes is the two-volume biography by David Brewster, published in 1855. At that time, the fashion was to write of historic personages in an adulatory mode. Brewster hailed Newton as the "High Priest of Science."¹ One of the positive features of these volumes is that they did make available some selections from the manuscripts belonging to the family of the Earl of Portsmouth, Newton's collateral descendants.²

Brewster's biography is notorious for the treatment of Newton's alchemy and his religious beliefs. Brewster simply could not "understand how a mind of such power, and so nobly occupied with the abstractions of geometry, and the study of the material world, could stoop to be even the copyist of the most contemptible alchemical poetry." How could a Newton take seriously and annotate the *De re metallica* of Agricola, which Brewster declared to be "the obvious production of a fool and a knave."

Although aware of Newton's unpublished writings on theological questions, Brewster either did not see or purposely ignored Newton's statements of disbelief in the doctrine of the Trinity. He praised the "wise discretion" of "Doctor Horsley," the eighteenth century editor of Newton's *Opera*, who chose not to make public Newton's statements about his religious beliefs.³

In retrospect, what is most disappointing about Brewster's biography, however, is not the attitude toward alchemy and religion, but rather the failure to illuminate our understanding of Newton's actual science and mathematics. Thus, in today's world, this work is not very useful to scholars and pales by comparison with the meticulously edited and copiously annotated edition of the Newton-Cotes correspondence, produced by J. Edleston. This work was

*This paper is dedicated to D.T. Whiteside and to Rupert and Marie (Boas) Hall, for their great contributions to our knowledge of the scientific thought of Isaac Newton.

first published in 1850 and it is still today a useful and important tool for Newton scholars.

Until the latter part of the nineteenth century, a huge collection of manuscripts by or relating to Newton was still in the possession of Newton's collateral descendants. These consisted of Newton's own records of correspondence (both letters to and from Newton), drafts of major and minor works, various kinds of essays on many different subjects, together with the documents assembled by John Conduitt (husband of Newton's niece) for a planned biography of Newton. These papers were inherited by the Conduitts' only child, who married Viscount Lymington, whose son was the second Earl of Portsmouth. This collection, generally known as the "Portsmouth Papers," was kept in Hurstbourne Castle until the Earl and his family decided that Newton's scientific manuscripts would be better preserved in some public repository. Accordingly, in the 1870s, what was called the "scientific portion" of the manuscripts was deposited in the University Library in Cambridge.

This enormous collection, rich in all kinds of materials relating to Newton's life — his thought, his work in mathematics, physics and astronomy etc. — was described in a published catalogue (1888), prepared by a University syndicate, whose members included the mathematical physicist G.G. Stokes and the astronomer John Couch Adams.

This catalogue is notably non-revealing. The descriptions are brief, laconic to the extent of being useless, hardly revealing either the quality or the extent of the items in question. One of the positive features of this catalogue was an introductory essay, of which a portion was obviously written by Adams, who revealed some of the astronomical and mathematical treasures he had found, including materials on the lunar theory and the solid of least resistance.

Over the next decades, this extraordinary hoard of Newtoniana attracted little scholarly attention and was hardly used. One of the few who even deigned to look at any of these manuscripts was W.W. Rouse Ball, known today chiefly for his popular book on "mathematical recreations."⁴ His books did not make the world cognizant of the great treasures awaiting study in the University Library.

Between the time of the gift of the Portsmouth Papers and the 1930s, there were a few others who did make some use of this vast collection. The work of these scholars, however, did not declare to the world at large the importance of studying Newton in the original sources. In trying to understand why this was so, we must remember that in those decades there was as yet no real discipline

of the history of science and of mathematics. Much of the writing in these areas was then produced by scientists or mathematicians in their retirement or scientists indulging in a hobby. The number of individuals who produced lasting historical contributions in the history of science and mathematics was small, including such heroic figures as J.L. Heiberg, G. Eneström, Thomas Little Heath and Paul Tannery.

An index of the lack of response to the existence of great source materials in the history of science and mathematics is the relatively small use made of the great edition of the "Oeuvres" of Christiaan Huygens. In terms of completeness of edited texts — correspondence, manuscript drafts and notes, completed published works — there is no other edition of the papers of a scientist or mathematician comparable with this one. And yet in the 1920s, 1930s and 1940s, there was not produced an adequate full biography of Huygens and scarcely any noteworthy studies on Huygens's science and mathematics.

In 1934, Louis Trenchard More, Dean of the Graduate School of the University of Cincinnati, published a 675-page biography of Newton. Even though More did make some use of manuscript sources, quoting or citing many hitherto unnoticed documents from the Portsmouth papers (from Cambridge as well as from those still remaining in the possession of the family), his book did not spark a new interest in Newton, either in the personality of this extraordinary man or in his scientific work.

There are a number of reasons why this was so. First of all, the times were not as yet ripe in terms of scholarship in the history of science and of mathematics. More importantly, More's book is dull, incident following incident and topic following topic without much illumination. Newton is generally treated with such veneration that the real person scarcely emerges.

Additionally, More was an extreme arch-conservative in science. Thus, after lauding Newton's *Principia* as a work of equal greatness with Aristotle's *Organon*, he deplored the fact that "these two works, probably the two most stupendous creations of the scientific brain," were both "now under attack." The enemies were, respectively, "the relativists in physics," led by "Professor Einstein," and what he called "modern symbolists in logic" — a curious name for those developing mathematical logic or, as it was then often called, symbolic logic. More insisted that "Aristotle and Newton will be honoured and *used* when the modernists are long forgotten."⁵

More does deserve credit, however, for having stated frankly and clearly the nature of Newton's beliefs on such doctrinal questions as the Trinity and for

having published extracts of Newton's expressing his anti-Trinitarian beliefs. Yet, More did not provide any real illumination and understanding of Newton's science and mathematics. The almost 700 pages of this work do not contain a single diagram nor so much as a single equation or proportion.

As all Newton scholars are aware, the big event that almost changed the availability of Newtonian sources overnight was the sale at Sotheby's public auction in 1932 of the vast horde of Newton papers still belonging to the family of the Earl of Portsmouth. This sale was provoked by the need to satisfy the payment of death duties.

The sale dispersed Newton's papers to the far corners of the earth. There was a notable scholarly catalogue produced for the sale. It contained many generous extracts from documents hitherto unknown or inaccessible to scholars. The descriptions of the various manuscripts and other items put up for auction, together with copious extracts, revealed more about Isaac Newton as a person and about various aspects of the development of his scientific thought than More's biography of a few years earlier.

Prior to the late 1940s, however, the only reference in print that I know of, in which any use was made of these newly available manuscripts is a curious paper by John Maynard Keynes. Keynes, as is well-known, assembled a considerable mass of the Newton papers disseminated in the Sotheby sale; these are now in King's College Library. In particular, Keynes owned a number of manuscripts dealing with alchemy and with theological subjects.

On the basis of an examination of these manuscripts, Keynes produced a paper, first read to a group at Trinity College and later to the Royal Society Club. Keynes was no longer living when in 1946, the Royal Society somewhat belatedly celebrated the 300th anniversary of the birth of Isaac Newton. His brother Geoffrey — the surgeon, bibliophile and book collector — read this paper at the celebratory meetings, and it was published in the Royal Society's volume.

Entitled "Newton the Man," this essay has become famous for its radical portrayal of Newton. Keynes insisted that his reading of Newton's manuscripts revealed a Newton who was not "the first and greatest of the modern age of scientists, a rationalist, one who taught us to think on the lines of cold and untinctured reason." Rather than being "the first of the age of reason," Keynes presented Newton as "the last of the magicians," the "last wonder-child to whom the Magi could do sincere and appropriate homage." In short, Keynes denigrated Newton's mathematics and physics and his founding of celestial

dynamics, denying that he had been “the first and greatest of the modern age of scientists.”

The new Newton was to be considered “a magician” who “looked on the whole universe and all that is in it *as a riddle*, as a secret which could be read by applying pure thought to . . . certain mystic clues which God had laid about the world to allow a sort of philosophers’ treasure hunt to the esoteric brotherhood.” In today’s scholarly world of irrationalism and lack of respect for any realism in scientific truth, Keynes’ statements about Newton as a non-rational magician find an ever-growing sympathetic audience.⁶

As far as I know, the next work to be based on the Newton manuscripts was a pair of scholarly articles published by Rupert Hall in 1948 and 1957. The first of these dealt with one of Newton’s early notebooks, but the second one, entitled, “Newton on Central Forces,” used manuscript sources to explore the genesis and development of Newton’s concepts in dynamics. Despite the fact that Hall had shown how new insights into the development of Newton’s scientific thought could be found by studying the manuscripts in the University Library, his example was not immediately followed by others. Indeed, I think it fair to say that it was not until Rupert and Marie Hall published their volume, entitled *Unpublished Scientific Papers of Isaac Newton*, in 1962 that the scholarly world at large, the world of historians of science and of scientists and mathematicians interested in historical questions, became aware of some of the extraordinary new insights that were to be found by examining the unpublished Newton materials.

Of course, by this time, in 1962, several others of us had already begun our projects of using Newton manuscript materials. The Royal Society had undertaken the edition of the *Correspondence* of Isaac Newton, of which the first volume appeared in 1959, three years before the volume of *Unpublished Scientific Papers*. I myself had begun, in close collaboration with Alexandre Koyré, to study Newton’s manuscripts and annotated books in order to learn about the genesis and development of the concepts and methods of his great *Principia*. Some others, notably John Herivel (in 1959), had begun to publish the results of explorations in the Newton manuscripts.⁷ Even more important, of course, was the enterprise of D.T. Whiteside, eventually resulting in the eight magnificent volumes of the *Mathematical Papers of Isaac Newton* (of which the first volume appeared in 1967).

It is difficult to think of any work of scholarship of comparable magnitude produced in our time, any other which matches the stature of this tremendously

important work. For not only do we find here, in full display, the documents that mark the development of Newton's thinking in mathematics, but there are also extensive annotations and commentaries which provide more information concerning the development of the exact sciences in the seventeenth century than is available in most treatises. In short, this work — by any conceivable standard — is a landmark. In retrospect, what may be most remarkable about the *Mathematical Papers* is that this was the production of a single human being working without any assistants, save at the stage of proofreading, and that the whole job was completed in twenty-two years!

It should be noted that Rupert Hall's contribution to our understanding of Newton did not cease with the volume of *Unpublished Scientific Papers*, which he produced with his helpmeet Marie. Rupert and Marie produced together a number of scholarly papers, of which those on Newton's chemistry and alchemy are especially significant and not always fully appreciated. Furthermore, it was under Rupert Hall's direction and editorship, assisted by Laura Tilling, that the eight-volume edition of Newton's correspondence was finally brought to fruition. And it is not amiss to mention here, Rupert's later volume on the Newton–Leibniz controversy and his relatively short biography of Newton (short, when compared to Sam Westfall's monumental work), and his more recent study of Newton's optics.

Since the beginnings made by Tom Whiteside and Rupert Hall, many important sources have been produced for the use of Newton scholars, too many to be listed or even mentioned here. But I must take note of the Westfall biography, *Never at Rest* (1980), a fabulously rich resource book for almost any aspect of Newton's life and thought. And I am sure that everyone here will wish godspeed to Alan Shapiro's projected further volumes of his important edition of the *Optical Papers*, a scholarly endeavor of the highest order which commands the respect of Newtonian scholars. One of the purposes of our gathering here today is to pay tribute to Tom Whiteside and to Rupert and Marie Hall and to display some of the results of Newton scholarship that have made use of manuscript sources of various kinds — sources that were virtually unknown to scholars prior to the scholarly work of Tom Whiteside and the Halls and all the others who have followed in their footsteps.

As I have just said, I know of no work in the history of mathematics and the sciences that is on par with Tom Whiteside's edition of the *Mathematical Papers*. Of course, whenever one thinks of monuments in the history of science, that which leaps immediately to mind is the magnificent edition of the works

of Christiaan Huygens to which I have referred to earlier. But Tom's edition of the *Mathematical Papers* goes beyond the scope of the Huygens edition in one very significant feature: almost every item presented in *Mathematical Papers* is accompanied by Tom's extensive annotation and commentary — not only on strictly textual problems and the general historical aspects of the document (that is, when and where and why it was written, how it was received, and so on). Tom's running commentary, often with mountains of erudition packed tightly in a telegraphic style into a small compass, is in a class by itself — the equivalent in information and explanation of a whole library of scholarly books and articles. These historical commentaries and technical explanations or glosses are of enormous help to any reader who really wants to understand what Newton was doing and why he did so.

I know of no other mathematical or scientific texts that have been so completely annotated in a modern scholarly edition as these "papers" of Newton's. Recently, I had occasion to re-read some parts of Descartes's *Géométrie*, which — as many of you will know — is not the easiest of books to read. As I was studying this seminal text, I could not help but wish that some Tom Whiteside had produced an annotated edition on the scale of the *Mathematical Papers* to guide ordinary readers through the text and to help them understand the implications of each part.

How was Tom Whiteside able to produce so magnificent a tool for scholars? As I see it, he came to the project with several qualifications which in combination were needed for this assignment. First of all, he began with an unrivalled background knowledge of seventeenth century mathematics. He had steeped himself in this early mathematics while serving his time as a research student at the University of Cambridge and the evidence is available for all to read in the published version of his doctoral dissertation, "Patterns of Mathematical Thought in the 17th Century." Let me say, as an aside, that when I first got to know Tom he was just finishing his dissertation. At that time, Clifford Truesdell, the founder and editor of *Archive for History of Exact Sciences*, had appointed me as a member of the advisory board and so I had the honor (along with Carl Boyer) of recommending this work for publication. Truesdell later told me that he considered this to be the most important contribution he had published in the journal.

The second quality that Tom brought to the Newton project was his training in languages and the study of texts, a feature of his primary field of study (Romance languages) while an undergraduate at Bristol. A knowledge

of language and the ability to deal with expressions in foreign languages is a gift, but one that is honed by training. Tom not only came to the Newton project skilled in languages and able to read Latin, French, and German, he also had been introduced to the integrity of texts.

Although Tom Whiteside learned much about the nature of texts and text-editing from the works he studied at Bristol, he found the mode of studying texts boring to him. Yet he made his way dutifully through such authors as Vergil, Caesar, Cicero, Horace, Martial and, his favorite “Golden Age” author, Tacitus, along with Villehardouin, Rabelais, and Montaigne. He found the prescribed study of Latin and French authors so uninteresting that his active mind sought for another source of stimulation, which he found in reading books on the history of mathematics, including important works by T.L. Heath and O. Neugebauer and von Ecke’s edition of Pappus. As he was not adhering to the orthodox mode of study, he even came close to losing his honors status, which would mean forfeiting his state scholarship. Thanks to the creation of a new university general honours degree in Arts, Tom was able to combine work in languages and literature with logic. Cramming for the final exams by reading the French books he had not yet studied, he was able to do well enough for a good degree and at the same time exhibited his command of Latin prose by making a version in the style of Tacitus of a set piece in English. Later in life, Tom recalled that he had actually purchased and enjoyed using a French edition of Lucretius which had the Latin original and the French translation on facing pages, with the editor’s annotations at the bottom of the page. This is the form he later adopted in his edition of Newton’s *Mathematical Papers*, but he does not remember making a conscious decision to adopt the form used by this French scholar.

A third quality, or qualification, was an extraordinary gift to think mathematically. Repeatedly in the *Mathematical Papers*, as in other publications, Tom displays a command of mathematics itself that is all the more astonishing in one who for whom mathematics was not the major professional subject of study in college or in graduate school. Tom recalls that at Bristol he never took a formal course in mathematics, but he read passionately many works on the history of mathematics and worked up various topics in mathematics on his own. One subject that especially delighted him was algebraic geometry.

A striking example of Tom’s mastery of mathematics may be found in his reconstruction of the steps by which Newton produced a new proof of Proposition 10 of Book II for the second edition of the *Principia*. Newton’s

attention had been called to a fault in this proof, but only after this portion of the *Principia* had already been printed. Accordingly, Newton not only had to produce in short order a correct proof to replace the faulty one; he also had then to pare the new proof until it could fit in the available space. Only someone skilled in mathematics could fully understand the basis of the criticism of the original Proposition 10. Furthermore, because Newton was, on this occasion, as on so many others, a veritable pack-rat, saving every scrap of his development of the new proof, Tom Whiteside had to face the formidable mathematical task of figuring out the chronological order of these scraps and versions and then understanding Newton's mathematical procedure. Here his skill as mathematician served him well.⁸

My fourth quality that enabled Tom to produce the edition of *Mathematical Papers* is a gift for the study of handwriting. This has long served him in making transcriptions of Newton's manuscripts, but has also enabled him to date various drafts and versions with an astonishing degree of accuracy — tested on many occasions by later corroborative evidence. In my own work, again and again, I found Tom's ability to date Newton's manuscripts by the handwriting to be of enormous help. And he equally was of great help in identifying the handwriting of others for example, in the annotations found in various copies of the *Principia*.

There are yet other qualities that were needed in order to produce the edition of *Mathematical Papers*. One, of course, was an incredible gift of memory, the ability to remember and to keep in mind the individual parts of the vast number (literally thousands) of different manuscripts, so as to be able to recognize that a given document is related to another in a very different part of the collection. Of course, the most important quality of all is the gift of historical-mathematical insight, that undefinable aspect of the mind that shines through every part of this great work.

In thinking about ways to illustrate how Tom Whiteside's work has made a difference to our knowledge of Newton, or indeed of our image of Newton or of our understanding of Newton's thought, I have chosen two very different examples. In many ways, for me the most dramatic finding of Tom Whiteside is the importance of Descartes in the early formulation of Newton's mathematics. Before the edition of *Mathematical Papers*, our knowledge of this subject was based on what seemed to be irrefutable evidence of Newton's disdain for Descartes. There was the statement recorded by Pemberton that Newton regretted having begun his study of mathematics by reading the moderns rather

than the ancients. This was interpreted as indicating his regret at wasting time with Descartes's *Géométrie* rather than studying Euclid and Apollonius.

The second was the statement by Brewster that Newton's copy of Descartes's *Géométrie* was marked throughout "Error. Error. Non Geom." For some time it was thought that this might have been an exaggeration by Brewster, since there seemed to be no such copy in existence. But finally, in part due to Tom, this puzzle was resolved. Newton did make such marks in a copy of Descartes.

When such evidence concerning Newton's attitude toward Descartes was coupled with the conclusion of Book II of the *Principia*, the conclusion seemed certain: Descartes was not one of those who had exerted a formative influence on Newton.

But Tom changed that view entirely in so far as mathematics is concerned. He showed how Newton's early views of the calculus were forged while making a close study of Descartes's *Geometry*, not the edition in French in which he gleefully noted the errors, but the edition in Latin with the commentaries of Frans van Schooten and others. This introduced Newton not only to the mathematical concepts and methods of Descartes himself, but also the important innovations of the Dutch school who were van Schooten's pupils, notably Hudde and Huygens.

The revelation of this seminal role of Descartes, enriched by van Schooten, was paralleled by the recognition by Alexandre Koyré, at more or less the same time, of the ways in which some of Newton's concepts concerning motion were also conditioned by his reading of Descartes. Koyré showed us how Newton took from Descartes the concept of "state" of motion or of rest, and developed Descartes's ideas in his own formulation of Definition 3 and Law 1. I myself was able to confirm this particular indebtedness. Today, we are aware that the "*Axiomata sive leges naturae*" of Newton's *Principia* were a kind of transformation of what Descartes called "*Regulae quaedam sive leges naturae*" in his *Principia*.

This shift in the evaluation of the role of Descartes in Newton's thought was a dramatic one. I clearly remember a troubled colleague asking me how it was that scholars were now discussing the importance of Descartes in the development of Newton's thought. Like others of his generation, he had always thought that the subject of Newton and Descartes was epitomized by the second book of the *Principia*. Here, it will be recalled, Newton concludes by showing that vortices cannot exist, that the celestial system of Descartes

contradicts Kepler's laws of motion. Alexis Clairaut even went as far as to suggest that the sole purpose of Book II of the *Principia* was to destroy Descartes's system of vortex-based cosmology.

A second revelation made by Tom Whiteside was in his gloss on Proposition 41 of Book I of the *Principia*. Until recently, most scholars had limited their study of the *Principia* to the definitions and laws and then the first three sections of Book I. They skipped all the rest of Book I and also the whole of Book II, finally studying the first part of Book III and the concluding General Scholium. Indeed, it will be recalled that this is in fact Newton's own suggestion to readers in the beginning of Book III.

Today however, it is becoming generally recognized that we do not really begin to see Newton as the master of mathematical physical science until we get further along in Book I. Here we needed someone like Tom to guide us, to make clear, at the start, the exact nature of Newton's dependence on what he called "the quadrature of certain curves," or the ability to perform the integration of certain functions. Even more important, Tom's guidance made it evident that in Proposition 41, as elsewhere, Newton was actually making use of the calculus and that his very language, when read carefully, permits of no other reading. For example, when Newton writes about "the line element IK" which is "described in a given minimally small time," he clearly has in mind what we would call a distance ds described in a time dt . In short, the cluster of propositions around Proposition 41 are written in the language of the differential and integral calculus and thus their analytic character is only partially masked by their synthetic form of expression.

Our meeting today at the Royal Society is a celebration of two great contributions to Newtonian scholarship — by Tom Whiteside and Rupert Hall — notably their heroic efforts in producing and interpreting Newtonian and Newton-related texts on which all Newton scholars depend. I have mentioned earlier the seminal work of Rupert Hall, much of it done in concert with Marie, in revealing the extent of Newton's thought beyond the works he allowed to appear in print. Anyone engaged in Newtonian research, and indeed, in research on any aspect of the science of the seventeenth century, depends heavily on the extraordinary edition of the correspondence of Henry Oldenberg, first Secretary of the Royal Society, an edition produced by Rupert and Marie Boas Hall.

I have already mentioned Rupert's bringing to a happy conclusion the Royal Society's edition of the *Correspondence* of Isaac Newton and the stream of important scholarly articles produced by Rupert and Marie.

Earlier in this presentation, I have said that for most scholars, a real turning point was the volume of *Unpublished Scientific Papers*, which was edited by Rupert and Marie Hall. Let me demonstrate the seminal importance of this work by indicating three ways in which its contents have changed our general thinking about Newton's ideas. Of course, the primary quality of this work is that Rupert and Marie actually found, identified, and interpreted, a large number of documents, the very existence of which was then unknown to the scholarly world at large. The interpretive essays and commentaries by the Halls explained the significance of the new documents they had found and were presenting.

In retrospect, what may have been the most notable feature of *Unpublished Scientific Papers* was the editing and translating of Newton's essay, beginning "*De gravitatione et aequipondio fluidorum . . .*" The Halls recognized the significance of this document as Newton's response to a first contact with Descartes's *Principia*. Here we find Newton formulating major concepts concerning space, time, and motion, and also force and inertia, in a Cartesian framework, just as was the case for his mathematics. The publication of this essay, together with the Halls' introductory commentary, documented Newton's first full encounter with the philosophy of Descartes and wholly changed our idea concerning the influence of Descartes on Newton. The late Betty Jo Dobbs recently published her study of this manuscript and had concluded that it dates from a time just before the *Principia* rather than earlier. I myself have found corroborating evidence for this re-dating.

A second important contribution of *Unpublished Scientific Papers* was the publication of a set of papers relating to Newton's early thoughts about motion. These include what is, I believe, the first English translation made of the tract *De Motu*. Although this tract was published at least twice before, in the original Latin, the Halls not only gave the first English translation but also listed the various extant versions and gave extracts indicating the differences among them. Thus, for the first time, this earnest of the great *Principia* to come was made available in a form for general use by scholars.

Finally, a third revelation — and in some sense the most important of all — was the existence of preliminary versions of an introduction and conclusion planned for the first edition of the *Principia*, including some thoughts that finally appeared in the second edition of the *Principia* in the concluding General Scholium and in later Queries of the *Opticks*. The Halls also found documentary fragments relating to these rejected texts.

Until the Halls published their volumes, one of the great scholarly puzzles for students of Newton had always been that the first *Principia* ends abruptly in a discussion of comets. How could Newton have written so magisterial a work on Natural Philosophy without a proper conclusion? The Halls found the answer. He had planned a General Conclusion in which he would indicate, *inter alia*, how his findings might be extended into other domains of natural philosophy, suggesting how his findings in rational mechanics and celestial dynamics might be carried into studies of the physics of matter, notably the constitution of matter and the action of short-range forces between constituent elements of matter. Suggestions about how to explore these topics and other related subjects were also explored by Newton in the manuscript Preface which the Halls discovered, edited, and published, and which, like the abortive Conclusion, was also rejected by Newton and never completed. In retrospect, we can see that Newton was acting wisely in his decision not to burden his *Principia* with debatable and intimate speculations. There were enough topics which were bound to arouse hostility, such as the introduction of a gravitating force “acting at a distance,” a concept abhorrent to all scientists who were followers of the reigning “mechanical philosophy.”

There was another long-standing puzzle about the *Principia* which the Halls were able to solve. In the eventual General Scholium, which appeared for the first time in the second edition of the *Principia* (1713), a final paragraph discusses what Newton calls a “spiritus” or spirit. What did he mean? No one was quite sure. Professor Koyré even hazarded a guess that Newton may have had in mind the “spirit of God.” But the Halls solved this puzzle by finding some preliminary drafts, which they published for the first time. They discovered that the “spirit” which Newton had in mind was an aspect of the new science of electricity then being developed by Francis Hauksbee, whose relation with Newton was later the subject of several important monographic studies by the late Henry Guerlac. The Halls clearly showed that the kind of “spirit” Newton had in mind in the General Scholium was that of an “electrical” spirit, the active agent producing the various effects observed by Hauksbee and demonstrated to Newton at meetings of the Royal Society.

Before leaving the subject of the contributions of the Halls and of Whiteside, let me add a final word about paths of influence. I have stressed the production of texts and their interpretation by both Tom Whiteside and by Rupert and Marie Hall. But these three researchers have influenced generations of scholars by means of their published articles. Scholarly influence is also produced by

personal contact, by a laying-on of hands. At Indiana and later in London, the Halls have trained many young scholars and have also influenced many senior scientists and historians who have worked with them on research in the history of science. It should also be mentioned that Rupert later went on to become an important pioneering figure in the new discipline of the history of technology and Marie produced valuable and interesting studies of the history of the Royal Society.

I first got to know Rupert Hall in the 1950s, when I came to Cambridge to work on the Newton papers. He was then still a Fellow of Christ's and had already begun to publish articles about Newton. As he and I contemplated the vast store of information lying unread and unused in the various Cambridge repositories (remember this was before the edition of the *Correspondence* or of the *Mathematical Papers*) we discussed a joint endeavor which we envisaged as a two-volume work on *The Life and Times of Isaac Newton*. Obviously we never got around to producing such a large-scale work, but each of us did publish a shorter biographical account. Mine appeared in the *Dictionary of Scientific Biography* and his as a separate book, entitled *Isaac Newton — Adventurer in Thought*. The volume *Never at Rest*, the magisterial biography written by our friend, the late Sam Westfall, approaches our planned work in its grand scale.

I should like to conclude by mentioning a feature of Tom Whiteside's contribution to Newton scholarship. Tom has been a teacher in a number of different ways. Those who have been able to attend his Cambridge lectures on the history of mathematics may be envied their good fortune. But Tom has also been a teacher in other ways as well, primarily by being a most generous advisor to many Newton scholars who have sought his help. Some have gained knowledge of sources they were unaware of and others have profited from answers to specific questions. Many of us has have learnt much from the extensive commentaries (some running to thirty pages or more of handwritten text) that he has written about drafts of our articles or books. His generosity toward other scholars is legion and is balanced by a sharp critical sense that comes into action whenever he encounters shoddy work or pure bluff.

I cannot even count the number of occasions on which Tom Whiteside has been generous to me, in providing me with information about sources which I might not have known, or in correcting misapprehensions, or even in the giving of good scholarly advice. When Anne Whitman and I were doing our Latin edition of the *Principia* with variant readings, he (and also Mr Adolf

Prag) read the proofs of our variant readings, thus helping us to eliminate errors. When Ann Whitman and I were finally dragooned into producing a new English translation of the *Principia*, Tom's advice to us was of enormous importance and we followed his general suggestions for our procedure.⁹

Max Planck once wrote that he had had two great honors in life. One, of course, was to have made the fundamental discovery of the quantum of energy. The other, he declared, was to have been associated with Albert Einstein. I believe we can all be equally proud of the honor of having known, or having been influenced in our scholarly understanding, by Tom Whiteside and by Rupert and Marie Hall. Of them and their work, it can be said in the words of the statement concerning Sir Christopher Wren in St. Paul's Cathedral, "*Si monumentum requiris, circumspice.*" The greatest tribute to their scholarly work is to be found in the studies based on their foundations, of which a generous sample is provided in today's proceedings.

Notes and References

1. This phrase, "High Priest of Science" was lifted by Brewster from the eighteenth century accounts of Newton written by William Stukeley, an antiquary who had actually conducted a sort of oral history interview with Newton.
2. It was long thought that Brewster based his biography on a complete examination of these manuscripts, that he himself had made the selection of those he published or mentioned. The researches of D.T. Whiteside, however, revealed that Brewster had not actually had free access to all the Newton papers, but had only certain selections made for him by a younger son.
3. Almost a hundred years later, Louis Trenchard More, the next major biographer of Newton, who actually published texts of Newton's showing his unquestioned Unitarian beliefs, criticized both Horsley and Brewster, adding that there "is nothing in his [i.e. Newton's] life so serious that it should have been suppressed." I have always found this statement to be odd, since it implies that a biographer *should* suppress things in the life of the subject that are "serious".
4. Rouse Ball made some use of Newton's manuscripts in his *Essay on Newton's Principia*, publishing a transcript of a version of Newton's essay "De Motu," previously published by Rigaud from the copy in the Royal Society, and also some samples of correspondence. In another volume, called

Cambridge Studies, he included an essay by Newton on a plan for education in the University.

5. L.T. More also devoted more than a page to defending Newtonian physics against “Professor Einstein” and the “relativists”.
6. This paper is a curious production. For example, there is no specific reference to a single manuscript or text, to any particular document. Furthermore, there is not a single quotation from Newton. In considering this paper, we should keep in mind that this was not a scholarly contribution written by Keynes as a serious well thought out essay intended for publication.

Keynes wrote it for a Cambridge audience, who would welcome a presentation that was brilliant, challenging, daring, and unorthodox. It is hardly the kind of serious production that one would normally expect as part of a celebration of Isaac Newton.

7. In the Preface to *Unpublished Scientific Papers*, Rupert and Marie Hall call attention to a bare handful of scholars who had used the Newton manuscripts. The list is short, but it does include a beginning made by Alexandre Koyré and the first essays of John Herivel, whose later volume of texts is regularly cited by Newton scholars.
8. The extent of this labor can be fully appreciated only by a study of the more than a hundred pages of texts — version and emendation after version and emendation — identified, transcribed, and edited by Tom Whiteside, and explained by him in a book-length gloss on these documents (for which see *Mathematical Papers*, Vol. 8).
9. In particular, I will always be grateful to him for advising me not to worry lest our version (published in 1999 by the University of California Press) contains some (inevitable) errors that might arise because we did not fully understand every possible point in this large and complex work. Tom told us to go ahead and not to be concerned, to print our version “warts and all.” Critics, he said, will call attention to errors which can then be corrected in a later edition. Another valuable piece of advice was that we should not compare our own versions with Motte’s or with any other translation until we had made a complete translation of our own and revised it fully.