INTRODUCTION

'MIND ALMOST DIVINE'

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"Whosoever to the utmost of his finite capacity would see truth as it has actually existed in the mind of God from all eternity, he must study Mathematics more than Metaphysics."

Nicholas Saunderson, *The Elements of Algebra*[1]

AS WE ENTER THE 21st CENTURY it might be possible to imagine the world without Cambridge University's Lucasian professors of mathematics. It is, however, impossible to imagine our world without their profound discoveries and inventions. Unquestionably, the work of the Lucasian professors has "revolutionised" the way we think about and engage with the world: Newton has given us universal gravitation and the calculus, Charles Babbage is touted as the "father of the computer", Paul Dirac is revered for knitting together quantum mechanics and special relativity, and Stephen Hawking has provided us with startling new theories about the origin and fate of the universe. Indeed, Newton, Babbage, Dirac, and Hawking have made the Lucasian professorship the most famous academic chair in the world.

While these Lucasian professors have been deified and placed in the pantheon of scientific immortals, eponymity testifies to the eminence of the chair's other occupants. Accompanying "Newton's laws of motion, "Babbage's principle" of political economy, the "Dirac delta function" and "Hawking radiation", we have, among other things, "Barrow's proof" of the fundamental theorem of calculus, the "Saunderson board" (a calculating instrument for the vision impaired), "Waring's theorem" of integers, "Airy's criterion" of telescopic resolving power, "Stokes's law" of fluid resistance, "Larmor frequency" of atomic precession in a magnetic field and "Lighthill's fourth law of engine noise." Small wonder, then, that scientific and historical literature, as well as a huge array of statuary, tombs, stamps, money, relics and the like, bear tribute to these colossal giants of science. Many of these homages, like the inscription on Newton's tomb in Westminster Abbey, put us mere mortals in our place:

> Here is buried Isaac Newton, Knight, who by a strength of *mind almost divine*, and mathematical principles peculiarly his own, explored the course and figures of the planets, the paths of comets, the tides of the sea, the dissimilarities in rays of light, and, what no other scholar has previously imagined, the properties of the colours thus produced. Diligent, sagacious and faithful, in his expositions of nature, antiquity and the holy Scriptures, he vindicated by his philosophy the majesty of God mighty and good, and expressed the simplicity of the Gospel in his manners. Mortals rejoice that there has existed such and so great an ornament of the human race![2]

Countless other tributes to Newton and his successors are equally as humbling. Take these lines from the obituary notice of George Gabriel Stokes published in the London *Times*:

> We may enumerate his scientific papers, we may expatiate upon his work in optics or hydrodynamics, we may dwell upon his masterly treatment of some of the most abstruse

> problems of pure mathematics, yet only a select body of experts can readily understand how great he was in these various directions, while possibly not all experts understand how much greater was the man than all his works … Sir George Stokes was as remarkable for simplicity and singleness of aim, for freedom from all personal ambitions and petty jealousies, as the breadth and depth of his intellectual equipment. He was a model of what every man should be who aspires to be a high priest in the temple of nature.[3]

Today, one can make a pilgrimage to a temple – the Cambridge-based Isaac Newton Institute for Mathematical Studies – to worship these high priests of nature. There, visitors are prompted by a series of artefacts to recapitulate the heroic story of the Lucasian professorship. Outside the building are three symbolic statues, representing intuition, genesis and creation, as well as an arboret descended from the Woolsthorpe apple tree that allegedly inspired Newton to invent his theory of gravitation. Upon entering they are presented with a bust of Dirac and a portrait, bust and death-mask of Newton. Clearly, we mortals have placed great value on the work of the Lucasian professors, and as a consequence much of their handiwork has entered the common coin of our (corruptible) world. We have put tremendous faith in the professors and their intellectual products. As trustworthy icons corporations even trade on their names. As well as being emblazoned on the old one-pound banknotes, Newton has been used to sell everything from apples to zenith telescopes. A chain of computer software stores is named after Charles Babbage; in Britain, Stephen Hawking, whether aware or not that his predecessor George Biddell Airy had invented a method for correcting astigmatism, has endorsed a spectacles retailer.

Even without spectacles – or Newton's telescope for that matter – the Lucasian professors are understood to see farther and with unparalleled perspicuity. The professors themselves have perceived this legacy. As a young, obstreperous reformer, Charles Babbage deemed Newton's *Principia* the "mill stone around the necks" of gownsmen; but in later life he reflected how the professorship had been "the only honour I ever received in my own country." The fiscally mindful Babbage gushed that "the names of Barrow and Newton have conferred on the Lucasian chair a value far beyond any which mere pecuniary advantage would bestow." Almost every other incumbent has shared Babbage's deep affinity with Newton. Upon graduating at the top of his class, Isaac Milner – later to be Cambridge's seventh Lucasian professor – was "tempted to commit his first act of extravagance. In the pride of his heart, he ordered from a jeweller a rather splendid seal, bearing a finely-executed head of Sir Isaac Newton." Other Lucasians have worked even harder to memorialise their predecessors. Stokes was asked to arrange and catalogue the unpublished optical papers of Newton bequeathed to Cambridge University Library by the Earl of Portsmouth, while Stokes himself was made part of that monument of late-Victorian hagiography – the *Dictionary of Biography* – by his successor, Larmor.[4] Most of the professors have been humbled by the gargantuan legacy that their predecessors bequeathed: "It is nice to feel that one holds the same position as Newton and Dirac," James Lighthill said, "but the real challenge," he admitted, "is to do work that is even a small fraction as significant." Although Stephen Hawking has criticised Newton's "vitriol and deviousness" he also feels close to the author of the *Principia*. As he has recently quipped, "Newton occupied the Lucasian chair at Cambridge that I now hold, though it wasn't electrically operated at the time."[5]

From Newton to Hawking recounts the ways these celebrated scientific thinkers have conceived their place within the history of the prestigious professorship. Of greater import, this book uses the context of the mathematical professorship to examine the extraordinary developments in the physical sciences since 1663. These changes relate not simply to the technical content of mathematical and scientific enterprises but the diverse array of uses to which such work has been put, from contemplating the origins of the universe to the design of quieter jet engines. In addition to this aspect of their work, their astonishing talent, tenacious industry and insatiable curiosity helps to explain why the Lucasians have dipped their hands in so many things. *From Newton to Hawking* explores the professors as antiquarians, alchemists, orators (Barrow has been called "one of the great orators produced by England"), theologians, economists, engineers, politicians and church-music composers, as well as pure researchers.[6] Accordingly, each chapter of this book provides a social history of mathematics, natural philosophy and physics and in so doing shows how the professors shared an intense preoccupation with the *application* of the sciences, both as reliable accounts of the natural world and as bases for such "non-scientific" subjects as faith, ethics, politics, and aesthetics.

Indeed, what emerges from this book is the significant extent to which these non-scientific topics permeated the enterprises of Lucasian professors at least as much as the research, administrative, and pedagogical duties associated with their position. For instance, Isaac Newton and his eighteenth-century successors were as determined to restore the basis of true Christian faith through a scientifically rigorous Scriptural exegesis as they were determined to promote the true (i.e. Newtonian) account of the natural world. Conversely, for professors like Charles Babbage and Paul Dirac, their "pure" mathematical research was a means for expunging the corrupted mathematical techniques which inevitably led to dangerous religious practices and troublesome secular ethics.

What the book is *not* is a reference work detailing the administrative details and tedious minutiae of the careers of the Lucasian professors. Nor is it a hagiographical account of disembodied scientific heroes. Alongside their magnificent triumphs are a number of spectacular failures, while the professors themselves have been the objects of scorn, jest, and chastisement. They have had sordid controversies with others and have squabbled amongst themselves. The career of Charles Babbage is illustrative: his calculating engine never functioned during his lifetime while it was said that "he never functioned as a professor." With his predecessor, George Biddell Airy, he had vigorous disputes over Britain's railway standards and the financing of his computers. He could also be off-putting, to say the least – the great Victorian historian, Thomas Carlyle, once reflected how "Babbage continues eminently unpleasant to me, with his frog mouth and viper eyes, with his hide-bound wooden irony, and the acridest egotism looking through it." These criticisms of Babbage also illustrate how readers of *From Newton to Hawking* will learn how Cambridge's most distinguished professors fit into (or not!) their contemporary cultures. The point that the professors are necessarily products of their time cannot be overestimated. Nevertheless, it is a point that habitually has been overlooked, ignored and suppressed. Through careful management of the history of the professors, previous accounts of the Lucasian chair – by both historians and by the chair's occupants – have made it appear that the professorship transcends time and space. Generally, these accounts have taken it for granted that the current professors inhabit the same mental world as their predecessors and present their work as a unified, cumulative and coherent "project".[7]

Like Newton's concept of "flowing time", this idea of continuity is seductive and it is surprising that no publication hitherto has attempted to provide portraits of these men as part of a continuous history. Not only have the professors inhabited the same town and institution, but many have shared the same laboratories, technicians and research programmes. And each professor, in his own way, has envisaged himself as a cog in the scholarly corporation, a kind of temporary placeholder in the eternal succession of professors. As Hélène Mialet suggests later in the book, the professorial Chair is akin to medieval kingship: although monarchs and Lucasian professors alike command great respect in the secular world, their temporal incumbency can seem relatively inconsequential compared to the everlasting corporate body they represent. If the professors themselves often remark that they are mere markers in a continuum of mathematical splendour, one cannot neglect the elements of discontinuity that problematise this grand narrative. One might try to imagine Stephen Hawking and Isaac Newton engaged in an animated conversation (or as *Star Trek* envisioned, in a poker game), but it is likely that their lives, careers and values would have been utterly alien to each other. While the interests, methodologies, habits and research areas of the different professors have been extraordinarily diverse, the sciences and the university itself have undergone radical transformations that make it difficult to compare professors from different eras. In 1663 the conception of the English university as a site of publicly funded experiment was still over two centuries away. Restoration Cambridge was not a research institution, nor would the varsity become one until the second half of the nineteenth century. Even Newton had trouble demonstrating to the republic of letters the value of mathematics and the protracted transition of Cambridge from chiefly a religious seminary to a scientific Mecca is an integral part of the professors' history.

I. A BRIEF HISTORY OF CAMBRIDGE

Henry Lucas, who had studied at St. John's College, believed that he recognised a breach in Cantabrigian scholarship. Wanting "to testifie" to his "affection" for Cambridge and for learning, he resolved to "ordaine … a yearly stipend and sallerie for a professor … of mathematicall sciences in the said Vniversitie." In his will Lucas said that his endowment would "honor that greate body," as well as assisting "that parte of learning which hitherto hath not bin provided for."[8] Yet, although it is striking that the Lucasian professorship was not endowed until the university was over four centuries old, it is, of course, misguided to suppose that the varsity was somehow incomplete before a professor of mathematics began to grace its schools. Though it may *seem* so to us, the infiltration of mathematics into the Cambridge curriculum was not inevitable. In many senses Cambridge functioned eminently well without a mathematics professor. On the one hand, Cambridge produced plenty of able mathematicians without an endowed professorship, and there were plenty of tutors capable of guiding undergraduates through the rigours of the curriculum. On the other hand, the university's function had little to do with state-of-the-art mathematics. John Wallis – who studied at Emmanuel College in the 1630s before embarking on a career at Oxford as the Savilian Professor of Geometry – commented on the general low regard for mathematical studies in relation to the purpose of the English universities: "Mathematics … were scarce looked upon as *Academical* studies, but rather *Mechanical*; as the business of *Traders*, *Merchants*, *Seamen*, *Carpenters*, *Surveyors of Lands*, or the like." Wallis realized that this opinion concerning appropriate scholarly learning reflected certain interests which had been formed centuries earlier. For, before the Reformation, Cambridge's central mission revolved around its service to the mighty Roman Church, the university serving to train prospective priests. Following the Reformation, Cambridge became *the* site to seek ecclesiastical preferment within the Anglican Church. Accordingly, all undergraduates – whether preparing to return to their estate, to make their way in London at the Inns of Court or to enter holy orders – embarked on a strict regimen of religious tuition and prayer at their colleges, a tradition that was not short-lived. Charles Babbage reminisced how "the sound of the morning chapel bell …

call[ing] us to our religious duties" was the only thing that compelled him and his fellow undergraduates to end their night-long devotions at whist.[9]

Alongside his antipathy towards chapel, Babbage also "acquired a distaste for the routine of studies." In his opinion the curriculum of the early-nineteenth century was antiquated, despite – or because of – its heavy emphasis on the Newtonian philosophy. For Babbage, the university had suffered from its Elizabethan legacy which from the sixteenth century had greatly influenced the trajectory of learning and examinations. During the reign of Elizabeth and the next two Stuarts college tutors confronted undergraduates with subjects from the *trivium,* the *quadrivium*, and the philosophies, their studies likely including logic, rhetoric, Aristotelianism, geometry, astronomy and some natural philosophy. By the middle of the seventeenth century tutors occasionally foisted the new natural philosophies upon their charges, and as an undergraduate it seems that, along with Aristotle and Virgil, Isaac Barrow received a dose of Cartesian philosophy. The mandate produced able scholars, but not professional mathematicians.

The Elizabethan statutes also determined how learning was to be *displayed.* In Barrow's time, oral examinations or "disputations"– not particularly conducive to testing mathematical skills – dominated the evaluation of hopeful sophomores and seniors. Pomp, ritual and ceremony were the order of the day as students tried to convince examiners, and perhaps the occasional royal observer, that they commanded the emblems of good scholarship: "To call these disputations merely debates between students," one historian has observed, "is like describing a Spanish bullfight as the killing of a cow". Even with the "Newtonianisation" of the curriculum, the rites and the spectacles associated with the Senate House Examination remained vital to the institution. Rather than radically overhauling the examination process, mathematical and scientific subjects came to dominate the exams through a glacial process of accretion. Only gradually did the Lucasian professors come to play a role in the process.[10]

The history of the professorship is also bound together with that of the colleges. Through the benefices of diverse wealthy patrons, the colleges had been founded one by one, sprinkled liberally throughout the commercial town, and each virtually independent from the others. Their wealth determined the extent to which each constructed its chapels, halls, common rooms, libraries, dorms and gardens. Regardless of their assets every college armed itself with a battery of bedmakers, cooks, porters and wine stewards to serve its master, tutors, fellows and students. As every Lucasian professor swiftly ascertained upon his matriculation, collegiate academia was decidedly *un*-egalitarian; a strict social hierarchy governed even the minutia of academic life. While aristocratic students wore resplendent garments and dined on high table, lesser born students tended to be at the bottom of the social heap. Both Isaac Newton and Isaac Milner entered Cambridge as humble "sizars" at their colleges and, accordingly, they were humiliated with chores ranging from ringing chapel bells to emptying chamber pots. One could rise from such humble beginnings to triumph within the intricate political fabric of the colleges. For instance, colleges ministered a number of parishes, and "meretricious" fellows could be presented with these "livings". Yet, as several Lucasian professors discovered, it took plenty of dexterous politicking to rise within the collegiate ranks. Apparently Barrow was blessed with such dexterity: he managed to procure the mastership of mighty Trinity College. Despite his enormous genius, Barrow's successor was perhaps less savvy in college politics. Newton's attempt to secure the provostship of King's College was a dismal failure. On the other hand, Milner, who like Newton had entered Cambridge as a sizar, ended up the 28th President of Queens' College. Moreover, as John Gascoigne points out in his chapter, the colleges and the central university have continually grappled for supremacy in Cambridge. In terms of the Lucasians, this incessant ebb and flow between University and colleges could dramatically affect the professors, both in terms of their status and in terms of their role in the instruction of students. Often, in this regard, the colleges were pre-eminent, and during these periods of collegiate ascendancy the Lucasian professor was somewhat marginalised in the academic community. Historically, most colleges found that it was *not* in their interests to have a Lucasian professor. College tutors were quite happy to set academic standards for young gownsmen and often viewed professors as little else than meddlers.

Nevertheless, the late-Georgian, and then the Victorian, professors began to leave their mark, first as examiners for the prestigious Smith's Prize in mathematics and then as influential proponents of curriculum reform. Even though the professors considered "Mathematics as the Key to Philosophy, as the Clue to direct us through the secret Labyrinths of Nature," the struggle was always uphill. Many late-Georgian proponents of liberal education did not see great value of mathematics to those other than "vulgar artisans." As a freshman Gilbert Wakefield grumbled that Euclid was nothing more than an "old carpenter." Yet, with the prodding of the Lucasian professors, gownsmen came to recognise mathematics as an integral part of the philosophical enterprise. After graduating Second Wrangler in 1776 even Wakefield changed his tune: "But happy that man! who lays the foundation of his future studies deep in the … *mathematical* philosophy: ... Language sinks beneath contemplations so exalted, and so well calculated to inspire the most awful sentiments of the GREAT ARTIFICER."[11] Thanks in great part to the professors, the varsity began to see the great value of Newtonianism and the mathematical sciences. Thanks also to them the Mathematics Tripos, which had evolved from the Senate House Examination, was seen as the most "meritocratic" form of evaluating students and it thus became the most prestigious Cambridge examination. By the 1830s, candidates were judged on their ability to tackle questions written in English on printed papers – the form that pervades most examination systems to this day. Victorian legatees of these exams, such as Stokes and Larmor, sat for approximately twenty hour-long papers over a three week period. After their exhausting labours they would await very public glory or humiliation as they were ranked as either a wrangler (first class), a senior *optime* (second class), or a junior *optime* (third class).[12]

Since high wranglers had better chances of obtaining fellowships and respectable employment, the Mathematics Tripos also fostered the growth of private mathematical coaching, and coaches shaped the minds of future professors like George Gabriel Stokes and Joseph Larmor. Although not formally recognised by the university, "pupil mongering" became such an important part of mathematical instruction that one distinguished Tripos graduate could reminisce in 1912 that "had there been no chair in mathematics in the University it is probable that the history of the School [of mathematics] would have been practically unaltered".[13] Another reason why this may seem so is that in the first half of the nineteenth century, the dominant figure in changing the content of mathematical instruction was *not* a Lucasian professor, but William Whewell. As a young don, Whewell had welcomed the efforts of the Lucasian professors Charles Babbage and Robert Woodhouse to introduce Continental methods of mathematical analysis into the curriculum. By the 1830s, however, the administratively omnipotent Whewell had become suspicious of analysis. It may have been suitable for advanced mathematical *research* but it was not suitable for Cambridge mathematical *teaching*, whose principle goal was to furnish the nation's future clergymen, lawyers, civil servants, and teachers with a "liberal education", notably the stable mathematical principles provided by such "permanent" subjects as Euclid's geometry, and Newton's mechanics. Whewell's "re-geometrisation" and "re-Newtonianisation" of the

Tripos in 1848-49 split the Mathematics Tripos into two parts – the first consisting of questions on geometrical and non-analytical topics, and the second, which could only be taken on succeeding in the first part, embraced the more sophisticated analytical subjects.

With Whewell at the helm, the new and progressive sciences of heat, electricity and magnetism were also excluded from undergraduate teaching. However, by the 1860s the importance of electricity and magnetism in educational curricula had risen sharply owing to the rapid development of the electric telegraph industry, a commercially, and imperialistically crucial enterprise. Furthermore, the researches of high flying wranglers like William Thomson and James Clerk Maxwell gave these new sciences a rigorous mathematical foundation and thus secured them a "permanent" place in the Cambridge curriculum. This was part of a wider change in mid-Victorian transformation of science teaching in Cambridge, a change owing much to the efforts of an 1850 Royal Commission to help the ancient British universities provide scientific instruction in line with the "requirements of modern times".[14] The university had already responded to the burgeoning need to prepare students for the industrialised modern times by founding the Natural Sciences Tripos (first examined in 1851). It continued to respond from the 1860s by creating new professorships and buildings. Long gone were the days of Isaac Newton and Isaac Milner, both of who had constructed their laboratories in their private residences. By the end of the nineteenth century the "New Museums Site" boasted (along with museums of zoology, botany and mineralogy), laboratories, workshops, and an optical and astronomical lecture room for the Lucasian professors.[15]

Despite these advancements, the nineteenth century Lucasians were often exasperated by the sluggish rate of change, as well as their remuneration. In 1857, eight years into his professorship, Stokes frequently wrote to his fiancée, agonising over how they might achieve that desideratum of bourgeois Victorian society – respectability in married life. Reflecting on the deliberations of a University Council enquiry into the endowment of professorships, Stokes suggested that his position would be improved if fellowships remained open to married dons. "If I were called into residence and my Fellowship were added to the Professorship", Stokes explained,

> our situation would be far, far pleasanter. I should be in a fixed and highly respectable position instead of being like a "bookseller's hack" as Airy expressed it to me. … I should do one thing well (at least I hope so) instead of having so many dissimilar things to attend to that I feel as if I were doing them all badly. I should have (probably) much more leisure for researches, which would then become part of my business, to keep up the reputation of the Chair .[16]

Stokes was initially disappointed since his college, Pembroke, did not abolish its celibacy restrictions on fellowships for another decade. Like many Victorian physicists, he had to provide for his new family with teaching and administrative "hackwork". In 1860, however, most of the original Lucasian statutes were officially repealed, bringing the chair in line with professional academic positions elsewhere in the country. While they gave the Vice-chancellor and elected officers the power to "admonish" or sack the professor if he was "wilfully neglectful of his duties, or guilty of gross or habitual immorality," the statutes also raised the income of the professorship by dipping into the money from Lady Sadler's benefaction of 1710. In 1886 the university channelled further monies into the Lucasian chair whose income had fallen owing to effects of the agricultural depression on the Bedfordshire estates on which the original endowment depended. By 1914 the professorship was regulated by the same statutes that governed most other university chairs, with the holder's main duty being to "devote himself to the research and the advancement of knowledge in his department and to give lectures in every year."[17]

These nineteenth-century transformations, along with Stokes's enthusiasm for both the mathematical and natural sciences Triposes, made Cambridge sciences a popular choice for undergraduates. But like many Victorians, Stokes was more sceptical of another change that was to affect the work of the Lucasian professorship, let alone that of other Cambridge pedagogues: the admission of women students. As Gillian Sutherland has written, "Cambridge was initially hostile towards women with academic ambitions, deeply reluctant even to tolerate their presences and for a long time treated them as marginal figures." Indeed, until the late-nineteenth century, most Lucasian professors considered cleaning and cooking to be the only appropriate activities for females within college gates. Before Victoria's reign, most official references to women were in the form of decrees by the Vice-chancellor concerning "provisions against public-women." Thus, in an age when the "weaker vessel" were seen as distractions from serious study, Newton once accused John Locke of having "endeavoured to embroil me w^{th} weomen".[18]

There were some exceptions to this general anxiety about the participation of females in the philosophical enterprise. In an attempt (albeit patronising) to include women in the study of mathematics, Nicholas Saunderson and John Colson collaborated on a translation of *The Lady's System of Analyticks* (though not published until 1801), written by their counterpart in Bologna, Professor Donna Maria Gaelana Agnesi. Despite its intended audience, Charles Babbage read the book as a freshman and admitted that from it he "acquired some knowledge."[19] Babbage's greater debt was to Byron's daughter, Lady Ada Augusta, who created, promoted and sustained a forum for his analytical engine. Ada Lovelace, however, was never a student at Cambridge, for it was not until Stokes's era that females were first admitted as undergraduates (although they were not granted full university membership until 1948!). And though Stokes himself worried that female students would "impair the heritage of men," his biographer reported how he "was much pleased when a Newnham lady who had attended his lectures brought him some original work which he approved."[20]

The twentieth century Lucasian professors have responded to changes from other directions, not least the dramatic increases in scale of experimental and theoretical physics, applied mathematics, astronomy, cosmology, and computing science. Neither Larmor nor Dirac had the size of international research schools boasted by Ernest Rutherford or Frederick Gowland Hopkins, but their careers exhibited the internationalism that was increasingly pervading the sciences, whether this meant attending international conferences, taking up overseas professorships, or managing trans-Atlantic professional relationships. With the notable exception of Lighthill, the work of twentieth century Lucasian professors could hardly be described as "big science" as far as the material cultures of their projects are concerned. And yet, their researches have depended on the dramatic development of large-scale research facilities. Larmor's and Dirac's evolving conceptions of the innermost structure of matter were built in conjunction with evidence generated across the globe, from Rutherford's Cavendish to Fermilab. Similarly, Hawking's revolutionary work on general relativity has been made possible by Cambridge's Mullard Radio Astronomy Observatory.

The steady expansion and rising status of twentieth-century Cambridge mathematics – both in terms of numbers of practitioners and sub-disciplines – is reflected in the establishment of two separate departments of mathematics, the Department of Applied Mathematics and Theoretical Physics (founded 1959) and the Department of Pure Mathematics and Mathematical Statistics (founded 1964). The increasing independence of Cambridge's departments of mathematics from the colleges is even more strikingly symbolised by one of the newest features on Cambridge's landscape: the Cambridge Centre of Mathematical Studies (completed in October 2001). This lavish new home for Cambridge's mathematics departments is geographically far removed from the colleges and close to those other jewels in Cambridge's crown of physical sciences – the (new) Cavendish Laboratory and the Institute of Astronomy (including the Royal Greenwich Observatory). It is also the place where the current Lucasian professor works and, owing to its physical proximity to its disciplinary brethren, can help the Lucasians develop even closer alliances with experimental physics and astronomy. This shift in geography also signals the diminishing significance of the colleges, the humanities' departments and the School of Divinity to the professors. It begs the question of how their principles have shifted over the course of four centuries.

III. THE PHILOSOPHICAL PRINCIPLES OF MATHEMATICS PROFESSORS

Shortly after Newton published his *Principia*, Richard Marsh, a divine ensconced in St. John's College, delivered a fiery sermon to his Cantabrigian cohorts. While many parts of western Europe were beginning to embrace the Newtonian philosophy, Marsh was distraught that mathematics would usurp revelation. From the pulpit he bristled that in the Mosaic account of Creation he met "with no *Laws of Gravity*." Rhetorically, he asked the modern philosophers, "what reason have I to believe the wonders of your *Comet*, more than any other Romance?"[21]

As well as the extent to which Newtonianism would be attacked as a philosophy antithetical to revealed religion, Marsh's brimstone is a telling reminder of the strong relation between religion and the scientific products of the Lucasians. For Newton this relation was, of course, intentional: as he told the Master of Trinity College, Richard Bentley, "When I wrote my treatise about our Systeme I had an eye upon such Principles as might work wth considering men for y^{e} beleife of a Deity & nothing can rejoyce me more than to find it usefull for that purpose."[22] Cantabrigian scholars had for some time viewed mathematical philosophy an efficacious means to contemplate the Grand Artificer. A generation before Newton's arrival in Cambridge, the King's College graduate William Oughtred addressed "*the english Gentrie*" when he was accused of neglecting his calling as an Anglican priest:

> in all ages many of the most eminent in the sublimity of Theologie, have beene also conversent in the study of the Mathematicks; … And in no other thing, after his sacred word, Almighty God (who creating all things in number, weight, and measure, doth most exactly Geometrize), hath left, more expresse prints of his heavenly & infallible truth, then in these Sciences."[23]

In particular, Newton regarded mathematical philosophy as a powerful instrument for combating the "pious frauds, false miracles & juggling tricks in matters of religion." Assuming that "gentile astrology and theology were introduced by cunning priests to promote the study of the stars," he presumed that by restoring the pristine natural philosophy of the ancients he could help eradicate the corrupted religious practices that he so despised.

Conceiving his labour to generate the *prisca sapienta* as a process of *re*-discovery, Newton placed himself within a conception of Time that, like the sectaries of the English Civil War and many Restoration natural philosophers, located his own lifetime as the critical overture to the Millennium. Accordingly, his successor in the Lucasian chair, William Whiston, commented that the *Principia* should be construed as "an eminent prelude and preparation to those happy times of the restitution of all things."[24] For Newton and several of the eighteenth-century scientific professors of Cambridge, the time had come for a true reading of the two Books – Nature and Scripture – and with it, the natural processes that would testify to the "renovation[,] regeneration or restitution of the y^{e} world and y^{e} second coming of Christ."[25] He was following a robust Cambridge tradition that the professors of the eighteenth century would perpetuate. While Newton had helped Thomas Burnet compose his 1681 *Sacred Theory of the Earth*, Whiston availed himself of the Master's mature mathematical philosophy to pen his 1696 *New Theory of the Earth*. Notably, Whiston used the properties of comets to exegete Scripture and bring Burnet's natural theology up-to-date. Adding to Newton's suggestion that comets deposited re-vitalising aethers to a spiritually depleted earth, Whiston equated comets with Hell: combining their apogaeic "Darkness of Torment" and their perigaeic "ungodly Smoak of Fire," comets became "the Place of Punishment for wicked Men after the general Resurrection."[26]

In comparing Whiston's confident exegesis to the work of his twentieth- and twenty-first-century successors, one might envisage the history of the chair as a reflection of the increasing secularisation of scientific knowledge. This interpretation is tempting. Take the materialism of Charles Babbage. In promising to reduce "Miracles" to pre-set "irregularities" in a his Analytical Engine, Babbage turned prophetic wisdom into a mechanical exercise: "the maker of the calculating engine," he gloated, "would thus be gifted with the power of prophecy." A century later Wolfgang Pauli wittily said of Dirac's spiritual leaning that he "has a new religion. There is no God and Dirac is his prophet." Among the numerous comments that Stephen Hawking has made concerning the relation of theoretical physics to religion, he has recently noted, "General relativity could not predict what should emerge from the Big Bang. Some saw this as an indication of God's freedom to start the universe off in any way God wanted, but others (including myself) felt that the beginning of the universe should be governed by the same laws that held at other times." Elsewhere Hawking has elaborated on this commitment:

> We are such insignificant creatures on a minor planet of a very average star in the outer suburbs of one of a hundred thousand million galaxies. So it is difficult to believe in a God that would care about us or even notice our existence. … [But] it is difficult to discuss the beginning of the Universe without mentioning the concept of God. My work on the origin of the Universe is on the borderline between science and religion, but I try to stay on the scientific side of the border. It is quite possible that God acts in ways that cannot be described by scientific laws. But in that case one would just have to go on personal belief.[27]

Hawking's religious beliefs certainly contrast markedly with those of most of his predecessors, for most Lucasian professors through the age of Stokes published theological works. While Newton, because of his heretical views, was unwilling to put his religious beliefs into print, the eighteenth-century professors were eager to demonstrate the accord between religion, the natural sciences and mathematics: among his prodigious outpourings Whiston published *A New Theory of the Earth* (1696) *The Accomplishment of Scripture Prophecy* (1708) and *Astronomical Principles of Religion, Natural and Reveal'd* (1717); in the 1730s John Colson demonstrated the breadth of his learning with his *Historical, Critical, Geographical, Chronological, and Etymological Dictionary of the Holy Bible*; to rebut David Hume's knock at English natural science and revealed religion, Edward Waring penned *An Essay on the Principles of Human Knowledge*; similarly, his successor and Doctor of Divinity, Isaac Milner, produced *An Essay on Human Liberty* in addition to his co-authored seven volume *Ecclesiastical History* in his bid to apply "knowledge of natural philosophy and mathematics to … stem the torrent of scepticism and infidelity … inundating this Empire"[28]

Nineteenth-century Lucasians were also active in producing religious ruminations. Alongside his hymns, Thomas Turton produced *Natural theology considered with reference to Lord Brougham's discourse on that subject* (1836) and was also immersed in the debate concerning dissenters' access to higher learning, providing his *Thoughts on the admission of persons, without regard to their religious opinions, to certain degrees in the Universities of England* in 1834. Irritated by the *Bridgewater Treatises*, eight best-sellers of the 1830s that upheld natural evidence for divine design and intervention, Charles Babbage penned his unofficial and fragmentary *Ninth Bridgewater Treatise* (1837), which retorted that miracles were not the result of Divine whim, but the product of natural law programmed by God. A generation later, attempts to reconcile the two Books by George Gabriel Stokes, a life-long evangelical Anglican, demonstrates that the history of the Lucasian chair is *not* a straightforward story of secularisation. Stokes's tenure coincided with potent challenges – by the likes of the authors of *Essays and Reviews* (1860) and champions of Charles Darwin – to the cultural authority of the established Church and the plausibility of the Biblical narrative. He responded with numerous religious tracts and books, including his Gifford Lectures of 1891–3, and addresses to Church Congresses. He was also President of the Victoria Institute, established in 1865 to uphold the belief that the claims of science and Scriptural truths were in harmony. This would lead his arch opponent, Darwinian champion and high priest of the "Church Scientific" Thomas Henry Huxley, to criticise angel "Gabriel" for abusing scientists by allying them with "everything Churchy & reactionary".[29]

Even where physics had been invoked by Darwin's guardians, Stokes did not think it had been done so legitimately. Instead, he evoked an immaterial gravitational force or luminiferous ether acting on ponderable matter in order to make plausible the notion of God guiding nature. Joseph Larmor was less vocal than Stokes, but he shared his predecessor's Protestant Irish upbringing and, as Andrew Warwick has suggested, protestant values underpinned his belief in measuring the motion of the earth relative to the ether. While the Irish Protestant physicist Frederick Trouton accused Larmor of becoming "much more catholic" in his "scientific beliefs" in accepting Einstein's Relativity, Larmor remained a "sturdy Protestant of Science" since he shared little with Einstein, remaining convinced that a dynamic aether was indispensable to an intelligible electromagnetic theory.[30]

Critical too for the "sturdy protestants of science" was a sharp distinction between the body and the intellect. Until Dirac's tenure, the Lucasian professors were "naturally led to observe a remarkable difference between the operations of matter and of the mind." Early-modern professors, like Isaac Milner, believed that it was critical to show that "immaterial substances are essentially different from material ones; and … seem to be possessed of certain active principles." Paradoxically, while the professors suggested that this ontological principle made the sciences subservient to religion, it also elevated the importance of their experimental work. Because of their unique understanding of the material world, the professors used their knowledge of the "established principles of Experimental Philosophy" to comment on "brute" matter's passivity and its dependence upon thinking substances. Newton's self experimentation with a knitting needle upon his own eye is illustrative: by showing that vision was contingent upon the voluntary actions of the mind (and *not* upon the manual manipulation of one's eyeball!) he felt that he had provided evidence against Thomas Hobbes's atheistic materialism. Similarly, during Victoria's reign, when physicist John Tyndall associated the relatively new principle of energy conservation with a materialistic and deterministic account of man's evolution, Stokes retaliated with his notion of "'directionism" which buttressed his intense Pauline dualism. He argued that an immaterial mind could direct energy flow in a material body and still be consistent with the new energy physics, making plausible the notion of mind independent of the corporeal body.

Hitched to this commitment to Cartesian duality has been a general wont by commentators to emphasise the difference between the professors' bodies and their minds. Disembodiment has become a vital ingredient in Lucasian lore. Famously, the Marquis de l'Hôpital wondered, "Does Newton eat, drink and sleep as other men do, or is he a genius deprived of bodily form?" More recently, Michael White has noted of Stephen Hawking's illness that "the disease has not touched the essence of his being, his mind, and so has not affected his work." Historians Steven Shapin and Christopher Lawrence have proposed that an underlying source of this familiar trope is the longstanding predilection to disembody knowledge claims since this makes them seem more authentic: "the worth of knowledge," they note, "has been linked to its stipulated elevation above the mundane and the corporeal." Since it has been assumed that physical perceptions by unreliable bodies have been consistent sources of the corruption of knowledge, truth and the body have been "pervasively set in opposition" and scientific practise has been readily disengaged from embodied investigators.[31]

Arguably, this is a reason why stories about the professors' indifference to the corporeal are plentiful. Paul Dirac's stoicism and monastic habitat are legendary and possibly only rivalled by his Cantabrigian contemporary, Ludwig Wittgenstein: "living in a simply furnished attic in St. John's College," Dirac "had a wooden desk of the kind which is used in schools" at which he apparently wrote his "great work straight off." It has been suggested that "he would have been a very contented martyr." For Dirac's predecessor, Joseph Larmor, running water and other twentieth-century conveniences seemed superfluous to good scholarship. One obituarist noted that he questioned "[modern trends even in such matters as the installation of baths in the College (1920)," and pooh-poohed demands for plumbing improvements: "We have done without them for 400 years, why begin now?" he proclaimed in a College committee. (Unsurprisingly, it was often noted that he neglected his appearance in his later age.). Newton was "so intent" upon his studies "that he ate sparingly," if he remembered to dine at all. One wit commented that "his cat grew very fat on the food left standing in his tray." Apparently, Barrow epitomised the dishevelled professor, being "scholarlike, negligent of his dress and personal appearance to a fault." "Once," Barrow's biographer continued, "when he preached for Dr Wilkins at St. Lawrence, Jewry, the congregation were so disgusted with his uncouth exterior that all but a few rushed out of church."[32]

The professors have not been utterly indifferent to the material world. Along with accounts of the their ambivalence to the mundane world are a number of counterexamples. These accounts have served several purposes: first, they have given the professors a human face and have shown that a healthy mind is contingent upon a healthy body; second, they have been used to help explain the mediocrity of particular professors; and third, they recount the heroics that are sometimes needed to pursue truth. So, while he initially saw no reason to have St John's re-plumbed, Joseph Larmor eventually capitulated to the bliss of hot water on tap: "once the innovation was made he was a regular user. Morning by morning in a mackintosh and cap, in which he was not seen at other times, he found his way across the bridge to the New Court baths." In contrast to the Marquis de l'Hôpital's aethereal portrait of Newton, others painted the professor as a robust scholar "Sir I[saac] thus exercised at once his body & his mind [a]s the operations of the soul depends upon the condition of the organs of the body …" Paulo Frisi also noted that "he had lost but a single tooth, he never made use of spectacles, he retained a lively eye, a venerale aspect and an elegant stature" And while Newton "gave up tobacco" because he was determined "not be dominated by habits," his predecessor, finding that it "tended to compose and regulate his thoughts," loved smoking. Barrow christened the New World leaf his "panpharmacon." In an age of roast-beef eating and beer swilling, the inaugural professor was also "inordinately fond of fruit." Nicholas Saunderson preferred his fruit fermented, and happily succumbed to a number of other worldly pleasures. He was renowned for his "indulgence of women, wine, and profane swearing to … a shocking excess." Half a century later Isaac Milner also proved that he could be a *bon viveur*. It is doubtful if he "indulged" in women, but he was not one to pass up a good meal or a fine bottle of claret. One astonished visitor to Queens' College reported Milner to be the "most enormous man I ever encountered in a drawing room." In contrast to the stoicism of Newton and Dirac, the evangelical Milner was also a whiner: "my whole life has been one of suffering."[33]

Milner was also "fond of describing himself an invalid" and used illness to shirk professorial duties. In this regard he was utterly unlike Stephen Hawking and Nicholas Saunderson, both who amazed the world by overcoming their disabilities. In his own lifetime the blind Saunderson confounded Europeans with his extraordinary memory, his impeccable hearing, his remarkable sense of touch and his ability to teach *optics*. Such were Saunderson's amazing skills that Denis Diderot imagined the professor to be the ultimate test of John Locke's theory of perception. Like Hawking, Saunderson's disability led him to develop novel techniques for manipulating equations in his head. While most scientists use reams of paper in their careers, the fact that neither Hawking nor Saunderson put pen to paper has meant that both found innovative methods to tackle, and produce novel solutions for, intransigent problems. Yet, while Saunderson's disability led Diderot to question God's benevolence, Hawking's amyotrophic lateral sclerosis has led twenty- and twenty-first commentators to think of him as a kind of angel. Deprived of a healthy body he has become an example of how a beautiful mind can triumph in a corrupt material world.

With the other professors, Hawking's essence has often been deemed spiritual and therefore not political; but, paradoxically, since the work of the professors has been understood to be unencumbered by social interests it is often deployed to serve very political interests. The four centuries that *From Newton to Hawking* spans were amongst the most dramatic in Britain's technological, economic, and social, and military history. It encompasses the industrial revolution and the arrival of the information age, the rise and fall of Britain's Empire, radical shifts in the social and political status of Britons, and countless bloody conflicts. Although they did not always comment on these wider contexts, the meaning of the Lucasian professors' achievements would be distorted if these contexts were not considered.

Beginning with its first incumbent, Lucasian professors have worked in the midst of great political ferment. Isaac Barrow, an exemplary Royalist, left England for a number of years while the ravages of England's Civil War and the Interregnum played out. Pointing to both his famous publications and his obscure manuscripts, historians now routinely talk of Newton's "politico-theology". As Newton himself affirmed, there was a strong "analogy between the world natural and the world politick." So, while Newton was composing his *Principia* in the mid 1680s, he was also feverishly penning his "*Theologiæ gentilis origines philosophicæ*," which detailed the defilement of ancient natural philosophy for political ends. Moreover, Newton, his followers and even his detractors understood that the 1687 *Principia* could be recognised as a piece of political science. Like Locke's political treatises, Newton's work was used to justify the Glorious Revolution and ensuing Whig hegemony. His mathematical philosophy, like the interpretation of Boyle's pneumatics by his colleague

Henry More, at once countered pure mechanism, the pantheism of sectarians, and the absolutism of Catholics. Conical sections, cometography, universal gravity and a mostly *empty* universe offered keys to a new Whig order and though the doggerel will not find its way into the literary canon, J.T. Desaguliers' 1727 *The Newtonian System of the World, the Best Model for Government* does exemplify how Georgian Britons could derive political messages from the Master's work.[34]

Similarly, we cannot properly explain the involvement of the Lucasian professors in the Longitude problem (notably Newton, Whiston, Waring and Milner) or in the production of better nautical almanacs (specifically Babbage and Airy) without appreciating the imperial, political, and economic importance of a strong Royal Navy. The Revolutionary era also weighed in heavily as the professors saw how science could be deployed to attack established rule. The cool reception of Continental analysis in Cambridge underlines how early-nineteenth century Britons associated European mathematics with the bloody French Revolution. The following generation of professors were less apt to cringe at mathematical and chemical works from across the Channel. Babbage's promotion of Continental mathematical tools for increasing efficiency in mental labour was inextricably linked to his contributions to fierce debates over the new factory system. By the 1840s the tools of Continental analysis were integral parts of Cambridge Mathematics Tripos. One beneficiary of this system was Stokes, who sought to provide the nation's future masters of industry with the practical and intellectual skills needed to sustain one of Britain's most powerful weapons of long-range imperial control – the electric telegraph. The telegraph helped keep the Empire together, something that both Stokes and Larmor, who as Irish Protestant Tories opposed Home Rule, were eager to see.

Other social and cultural shifts that have taken place in Britain in the century since Stokes's death have had a clear impact on the world of the Lucasian professor. The dramatic broadening of the educational opportunities of scholars are traceable in the transformed gender, social, and ethnic composition of the people working with the current Lucasian professor. The technological descendants of the Victorian telegraphic network have also contributed to the "information" revolution that has fed back into Cambridge mathematics. New media technologies have helped make Hawking the centre of a global, cutting-edge communication network in theoretical physics as well as an influential political commentator. Today's cultures of mathematics is exemplified by the new Cambridge-based "Millennium Mathematics Project" which fully exploits the latest web technologies "to help people of all ages and abilities share in the excitement of mathematics and understand the enormous range and importance of its applications to science and commerce."[35]

III. THE PROFESSORSHIP IN A NUTSHELL

Though none of the seventeen Lucasian professors of Mathematics would have described themselves as statisticians, their lives have generated some interesting figures. Thirteen of the Lucasians have been fellows of the prestigious Royal Society. Neither John Colson, nor Thomas Turton nor Joshua King could find either the backing or muster the energy to gain membership. Notoriously, Newton, as the society's president and being of a "fearful, cautious and suspicious temper," did not support Whiston's gambit for admittance.[36] Besides Newton, only one other Lucasian professor has been the Society's president – George Biddell Airy – although both George Gabriel Stokes and Joseph Larmor served as secretary. Edward Waring (1784), Airy (1831), Stokes (1893), Dirac (1952) and Lighthill (1998) all received the society's prestigious Copley Medal, while most others have been prominent within the Royal Society.

Other awards, decorations and honours have been showered upon the band. Although one only – Paul Dirac – has received a Nobel Prize (the prize was not established until 1901), more time-honoured rewards have been plentiful: five have been knighted (Newton, Airy, Stokes, Larmor and Lighthill) and one can reasonably expect that Hawking might soon be called "Sir Stephen." Isaac Barrow (Trinity), Isaac Milner (Queens'), George Gabriel Stokes (Pembroke), and Joshua King (Queens') were all rewarded with the mastership of their respective colleges, while University College London snagged James Lighthill as its provost. As discussed earlier, Newton's inability to secure the provostship at King's College was one of his few failures, though he was, however, elected to Parliament (twice), a triumph that is only slightly overshadowed by the fact that the only record of him speaking within the House of Commons was a request to have shut a draught-causing window. Alongside Newton, George Gabriel Stokes and Joseph Larmor also represented Cambridge as MPs while, famously, Charles Babbage twice stood unsuccessfully for the borough of Finsbury.

Most Lucasians have been concerned with eternal rewards, both for themselves and for their fellow Christians. Although none did so in the twentieth century, seven – Barrow, Whiston, Colson, Waring, Milner, Turton and Stokes – donned the vestments of the Anglican Church. Indeed, Thomas Turton was elevated to the see of Ely after he stepped down from his mathematics' chair. Such was his antipathy towards the Church established, that Newton sought a special dispensation from the King in order to avoid taking Holy Orders; but only the foolish have suggested that his evasion had anything to do with an inclination towards the secular.

Whiston, like Newton, loathed the doctrine of the holy and undivided Trinity. This deep commitment to Arianism leads also to another statistic: branded a heretic by the University's vice-chancellor, he is the only Professor to have been unwillingly removed from the Chair. Besides Whiston, none, to our knowledge, have been suspected of transgressing the professorial statute involving "treason, heresy, schism, voluntary manslaughter, notable theft, adultery, fornication or perjury." Nor do any past Lucasian professors seem to have arrested for any other crimes or misdemeanours. Accordingly, all but one election for the professorship has been precipitated by either wilful resignation or the death of the incumbent, the former being slightly more common. Resignation accounts also for trimming the average length of tenure – almost exactly twenty years. Stokes, weighing in for an astounding 54 years is almost singularly responsible for driving up the average: meanwhile the tenures of Airy, Woodhouse and Turton combined could not see through the 1820s. These Lucasians and the rest of the professors, however, have shared one obvious characteristic: they have all been white males.

These statistics are illuminating. They fail, however, to uncover the extent to which each professor has been embedded within the cultures in which he deployed his expertise. Along with a journey through the professors' great triumphs (and a few humiliating defeats), *From Newton to Hawking* travels through three-and-a-half centuries to find these diverse scientific cultures. Though readers of this book will discover some fascinating continuities over the duration of the professorship, these cultures will also show how different the professorship of the twenty-first century is from 1663, when the chair was endowed.

In the first chapter Moti Feingold recounts the protracted search for a benefactor with the wherewithal to establish a "*mathematicus professor honorarius* ... with a House of Purpose." While reminding us that the absence of the mathematical professorship should not be construed as a lack of mathematical activity at the varsity, he also shows why Henry Lucas's endowment and the work of the inaugural professor, Isaac Barrow, were so valuable to the institution. Although some commentators may have felt that Barrow was "but a child in comparison to his pupil Newton," Feingold convinces us that Barrow's profound and ambitious studies, and particularly his research in optics, cannot be taken lightly. In addition, he addresses an apparent paradox that the first Lucasian professor presents: although Barrow considered mathematics the "fruitful Mother of all Disciplines, and benign Nurse of all Studies," he was deeply resistant to publishing his mathematical work, even complaining to a fellow divine that he was "wasting [his] time and intellect" in mathematics. In pointing to the tension between Barrow's love for the mathematical sciences and devotion to theology, Feingold's portrait of Barrow sets the stage for discussion of his tormented successor.

Robert Iliffe's account of Isaac Newton masterly synthesises the radically diverse activities of the second Lucasian professor. Unearthing the full extent of Newton's intellectual activities and contextualising these within his Cantabrigian and metropolitan scientific milieux, Iliffe portrays the "Great Man" as a psychologically troubled mortal, but a mortal who believed that he was on a mission from God. Constantly distinguishing himself from "the vulgar," Newton conceived his divinely sanctioned role to involve the recovery of uncorrupted ancient truths, both scientific and religious. So, though we may remember Newton for his major contributions to mathematics, astronomy and optics, Iliffe tells us we must not forget that the "Great Man" was just as much a revolutionary in alchemy and theology. Only with an appreciation of these interests, can we begin to fathom the truly radical nature of Newton's work, not to mention the extent of his remarkable genius.

Newton was a hard act to follow. In his influential study of "Enlightenment Cambridge," D.A. Winstanley observed that "Cambridge in the eighteenth century was sadly lacking in eminent mathematicians." This pronouncement has been reiterated by the Lucasian professors themselves: "There is no doubt that there was a stagnation in scholarship in Cambridge throughout the eighteenth century," complained Sir James Lighthill: "this unreformed Cambridge was really bad. A great pity really."[37] But, in *From Newton to Hawking*, the chapters devoted to the eighteenth-century professors show that this supposition is unwarranted. Though the age may not have been an heroic one for Cantabrigian natural philosophy, it was nonetheless one of vibrant activity. Of course much of this activity was directed at interpreting, protecting and disseminating the unparalleled genius of Newton. Newton's work, the eighteenth-century Professors believed, had catapulted Britain into a new age. The judicious use of his philosophy would solve scientific, technological, religious and political problems. Along with "Newtonianising" other fields of enquiry from theology to medicine, it was therefore the mission of the eighteenth-century professors to broadcast the existing gospel of Newton. But what, exactly, this gospel *was* was open to debate, even amongst the mathematical professors themselves. Since his corpus was so gargantuan and so enigmatic, Newton's intellectual legacy was fraught with difficulties. Each professor found that he needed to interpret Newton in order to fight the growing number of enemies who found the Newtonian philosophy intellectually and morally bankrupt.

The "Great Man's" immediate successor, William Whiston, epitomised this ambition to defend Newton's work and to bring his "Divine Philosophy within Reach" of mortal Britons. Moreover, where Newton had held his theological cards close to his chest, Whiston brazenly – and, perhaps, cavalierly – applied the scientific reasonings of the *Principia* and the

Opticks to scriptural exegesis. In their treatment of his extraordinary attempt to render both Newton's philosophy and Scripture transparent (via Newton's natural philosophy), Stephen Snobelen and Larry Stewart follow Whiston's unconventional path from the private serenity of cloistered Cambridge to the public bustle of Augustan London. Banishment from Cambridge, they argue, was only one of many signs that Whiston was embroiled in the chief religious controversies of the era. By delineating his great success in the metropolis Snobelen and Stewart show also that his expulsion from the university, seemingly paradoxically, enabled a career boost as Whiston found "fame and fortune" in both metropolitan coffeehouses and in print. Whether "solving the Longitude" with exploding mortars, linking comets to Noahic catastrophe and "Divine Vengeange", or galvanising polite audiences with fantastic electrical phenomena, Snobelen and Stewart show precisely why it was difficult *not* to listen to Whiston.

With the rustication of Newton's successor from Cambridge, Edmund Halley quipped that "Whiston was dismissed for having too much religion, and Saunderson preferred for having none." Nevertheless, the story of Nicholas Saunderson and his successor, John Colson, is as much one of continuity as it is of discontinuity. Although neither professor antagonised the Anglican Establishment as did "wicked Whiston", both Saunderson and Colson emulated Whiston's endeavours to make popular the central tenets of Newton's *œuvre* and to vanquish detractors of the "Great Man". John Gascoigne pays special attention to the pedagogical enterprises of these two Lucasians. In so doing he shows also how their work chimed in with the other Cambridge Newtonians who, locking horns with the likes of Bishop Berkeley, were anxious to establish that Newton's philosophy led neither to "absurdity" nor to the "heresies of infidels". John Colson, for instance, saw Newton's *Method of Fluxions* to the press, not simply to give Britons better access to a powerful analytical tool but to ensure that the "visible and sensible form" of the fluxional calculus led directly to godly truths. Although not having access to the "visible," the blind Saunderson did give his mathematical practise a "sensible form" and this leads Gascoigne to a discussion of how the professor's physical disadvantage gave the Enlightenment minds of Denis Diderot, Samuel Johnson and Edmund Burke pause to consider relationships between sense experience, ideas and the nature of the Deity.

Like Saunderson and Colson, the following two Lucasian professors, the "awkward" and "melancholic" Edward Waring and the "arrogant" and "incomparable" Isaac Milner, were anxious to preserve the status of Cambridge dons as the authentic representatives of Newton and to use this status to quash the increasingly hostile attacks on the university. Touching upon the intellectual products of the Enlightenment and the major shifts in the sciences, as well as the revolutionary contexts of the *fin-de-siècle*, Kevin Knox shows how Waring and Milner dealt with the devastating critiques of Cambridge's scientific practice from such luminaries as Joseph Priestley and, later, the irascible Charles Babbage. Although remarkably dissimilar in personality, the two Lucasian professors shared common strategies for preserving the place of spirit in the natural world, the primary articles of the Anglican Church and the "traditions" of university life. Yet, Knox argues, it would be a mistake to regard these two Lucasians as mere reactionaries, for their participation in the national and international republic of letters signalled some new characteristics of the nineteenth-century don.

With Milner's death in 1820 neither reform of the institution nor of the Professorship looked promising. As an undergraduate Babbage had satirised a bitter religious dispute in which Milner was a key player in an attempt to launch a revolutionary mathematical society; but partially due to Milner's resistance, Babbage's "Analytical Society" fizzled. Nevertheless, in the following decades the Lucasian professors played important roles in making Britain the pre-eminent scientific state and in changing the university from a "gentleman's club" to a research institution. Concomitant with these transformations in the "holy city of mathematics" was the rising eminence of the professorship itself. In his account of the professorship from 1820-1838, Simon Schaffer recaptures the complex, and very divergent, interests of four Lucasian professors: Robert Woodhouse, Thomas Turton, Charles Babbage and George Biddell Airy. Along with vivid accounts of vicious electoral campaigns and combination room intrigue, Schaffer places the professors' interests within a precarious university culture that simultaneously insisted upon maintaining its rich-if-dated scholarly traditions but realised that it needed to come to terms with the new philosophies of manufactures, machinery and political economy. Expertly glossing the careers of Woodhouse and Turton – whose tenure was arguably the nadir of the professorship – Schaffer concentrates on the ambitions and anxieties of George Biddell Airy and Charles Babbage. In addition to surveying the instruments and techniques that eventually made Airy a model Astronomer Royal, Schaffer describes Babbage's obsession with improving the efficiency of Britain's Imperial economy through rationalizing the emerging mechanisms of the factory system. Literally mechanizing mathematical reasoning with his calculating engine, Babbage forced less progressive Cambridge men like William Whewell to rethink what scholarship meant for both the university and for the Empire.

George Gabriel Stokes was one of the new breed of Cambridge scientists that helped Whewell reformulate scientific practice at Cambridge and, indeed, throughout Britain. Contrasting the keen experimentalist with his competent-but-lacklustre predecessor, Joshua King, David Wilson portrays Stokes as a key arbiter of science. While producing groundbreaking research in optics and hydrodynamics, Stokes, as Professor and Secretary of the Royal Society, was in a strategic position to comment upon myriad subjects – both scientific and cultural – that captivated Victorians: the luminiferous aether, spiritualism, the immortality of the soul, x-rays, radioactivity and Darwinian evolution. As for the last, Wilson describes how for Stokes, Victorian physics not only generated accounts of the cosmos which could be reconciled with Genesis, but also symbolized the high standard of scientific reasoning that Darwinianism, that potent weapon against Creationism, failed to reach.

Stokes may have been the last Lucasian professor of Victorian Cambridge, but it was said of his successor, Joseph Larmor, that his "heart was in the nineteenth century." In his account of the twentieth century's first new Lucasian professor, Andrew Warwick examines Larmor's protracted quest to describe what he envisioned as the fundamental essence of the universe – a dynamical, luminiferous and electromagnetic medium. While some have viewed Larmor as a kind of anachronism unwilling to abandon an obsolete and fantastical concept, Warwick suggests that Larmor's work has been gravely misrepresented and unearths the underlying sophistication of the professor's dynamical ether. Larmor's dynamical ether, Warwick shows, was more than a convenient way of unifying electromagnetic and optical phenomena: it represented an ontological reality that made progress in physics possible and revealed the underlying unity of nature. So, in the face of widespread claims that the Michelson-Morley experiment had failed to generate evidence of the aether, Larmor insisted that his ether theory explained why this null result was essential to the construction of theoretical physics. Warwick explains why this in turn enabled Larmor to construct a natural history of physics that placed this aether at the locus of an ineluctable and benevolent process of discovery.

If Joseph Larmor is, somewhat unjustly, remembered for his reluctance to embrace new scientific theories, his successor, Paul Adrian Maurice Dirac is often memorialised for revolutionising physics with audacious claims about the nature of the sub-microscopic world. Nevertheless, Dirac shared with Larmor what might be called a non-empirical methodology for favouring physical theories. In his exploration of the life Paul Dirac, Helge Kragh delves into the unusual mental world of the Nobel laureate, using Dirac's vision of purity, rationality and beauty to excavate both the motives and the processes behind the professor's startling work. As a "pure soul", Dirac, Kragh explains, was obsessed with dissociating himself from the mire of traditional academia and scientific practice. As such, he usually worked in monastic isolation and was often viewed as an anti-social curmudgeon. Similarly, as a "fanatic of rationalism", he scorned anything that seemed to him to smack of social interest, be it in reference to an experimental research programme or a political ideology. Kragh explains how this rationality, seemingly paradoxically, was integrated with a deep commitment to mathematical aesthetics. Such was his fixation with this enigmatic aesthetic that Dirac was wont to equate beauty with truth, and even reject experimental evidence if it conflicted with his notion of a beautiful equation. Yet, despite his unorthodox attitudes and working habits, Kragh shows exactly why so much of Dirac's work remains central to modern, "orthodox" physics.

Central too to the orthodox scientific world – but also to a host of unconventional creeds – is the work of the current Lucasian professor: Stephen Hawking. In the final chapter of this volume Hélène Mialet examines the remarkable and courageous life of "the prophet of the black hole." Contrasting Hawking's career with that of his predecessor, James Lighthill, and considering both the professor's debilitating illness and the stunning theoretical achievements that helped make him famous, Mialet's ingenious analysis follows the route that turned the seemingly most mortal of men into a celebrated oracle. By virtue of the timeless professorship he represents, the panoply of machines and humans that enable him to work and the fact that his theoretical physics is often deployed in theological speculations, she argues that we can consider Hawking as a kind of angel who is at once seemingly immortal, immaterial and ubiquitous. Once considered a "stop-gap professor," Hawking has metamorphosed into a beatified media darling whose opinions are sought from the White House to the Vatican. In so doing he has become the quintessential Lucasian professor.

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The recent advances in computing, the technologies that keep Hawking at work and Hawking's own statements concerning "the end of physics" give Mialet pause to speculate about the future of the Lucasian Chair. Is it possible, she wonders, if the mathematical professors will one day become superfluous? Fascinatingly, the professors themselves have from the beginning wondered about this eventuality. In 1675, the first two Lucasian professors – Isaac Barrow and Isaac Newton – were pessimistic about further advances in mathematics and therefore, presumably, what future mathematical professors would do with their time. According to reports, Newton was "intent upon Chimicall Studies and practises, and both he and Dr Barrow &c [were] beginning to think math[emati]call Speculations to grow at least nice and dry, if not somewhat barren." This barrenness was a chimera, for, among other things, Newton's own "Queries" gave investigators plenty of fertile regions to probe.

Nevertheless, questions about the end of mathematical physics have resurfaced at the varsity. In 1874 James Clerk Maxwell reflected on a foreign "opinion" which "seems to have got abroad, that in a few years all the great physical constants will have been approximately estimated." While some foreigners worried "that the only occupation which will then be left to men of science will be to carry on these measurements to another place of decimals," Maxwell was confident that "the materials for the subjugation of new regions" were being sown.[38] The discovery of the electron, radioactivity and other dramatic events vindicated his optimism and gave physicists like Stokes new avenues of research. Yet, just a decade later Lord Kelvin, another close colleague of Stokes, speculated that accurate measurement was signalling a very different end for physics. He described two "clouds" over the dynamical theory of heat and light, a theory which most Victorian physicists – not least the Lucasians Stokes and Larmor – believed provided the most satisfactory unifying account of the physical world.[39] For Kelvin, measurements of the specific heats of gases and the apparent non-motion of the earth relative to the ether posed serious problems for the equipartition theorem of energy developed for molecular behaviour and the electromagnetic ether.

These problematic cornerstones of classical physics were eventually "dispersed" by two monuments of post-classical physics – Planck's quantum theory and Einstein's theory of relativity. These monuments gave both Paul Dirac and Stephen Hawking the opportunity to posit startling new conceptions of the universe; but by the end of the twentieth century it seemed that with the apparent unification of quantum mechanics and relativity theory post-classical physics was at an end too. In his 1984 best-seller *The Brief History of Time*, Hawking cautioned that this goal had many "false dawns", including Max Born's notorious remark – made after Dirac had constructed his relativistic equation for the electron – that "Physics, as we know it, will be over in six months". Yet Hawking has also declared that since "we know so much more about the universe … there are grounds for cautious optimism that we may now be near the end of the search for the ultimate laws of nature". Part of his optimism may relate to the astonishing advances in computing, advances that have led Hawking himself to quip that he is "Intel inside." It is doubtful, however, that Hawking equates the capacities of silicon chip with artificial intelligence (AI), and it seems that in this millennium the investigations of the Lucasians will continue to be a very human enterprise. As Henry Lucas envisaged, the Lucasian professor will continue to "be a man [or woman] of good character and reputable life, at least a Master of Arts, soundly learned and especially skilled in the mathematical sciences."[40]

ENDNOTES

[1] Nicholas Saunderson, *Elements of Algebra, in ten books: to which is prefixed, an account of the author's life and character, collected from his oldest and most intimate acquaintance* (Cambridge, 1740) 2 vols, ii, 740.

[2] English translation of Newton's Westminster Abbey tomb in G.L. Smyth, *The Monuments and Genii of St. Paul's Cathedral, and of Westminster Abbey*, 2 vols, (London, 1826), ii, 703-4.

[3] *Times*, 3 February 1903, 7.

[4] Mrs. Laurence Humphry, "Notes and Recollections", in Joseph Larmor (ed.), *Memoir and Scientific Correspondence of the Late Sir George Gabriel Stokes*, 2 vols, (Cambridge, 1907), i, 24; J[oseph] L[armor], "Sir George Gabriel Stokes", *The Dictionary of National Biography* (hereafter cited as *DNB*).

[5] Charles Babbage to C. Wordsworth, 14 November 1826, British Library, Babbage Papers, 37183 f.366; Charles Babbage, *Passages from the Life of a Philosopher* (London, 1864, 1994), 24; see also 18-29. Mary Milner, *The Life of Isaac Milner D.D, F.R.S.* 2 vols. (London, 1842), i, 8. Lighthill in interview conducted with James Lighthill by Robert Bruen, July 1998: http://exile.ne.mediaone.net/lucas/lighthill-interview.html. Stephen Hawking, *A Brief History of Time* (New York, 1988) 182; Stephen Hawking, *The Universe in a Nutshell* (New York, 2001).

[6] Barrow's skills in T[homas] F[rederick] T[out], "Isaac Barrow", *DNB*.

[7] For Babbage's malfunction, and reminiscences of him, see *DNB*; for Babbage's controversies, see Babbage, *Passages*, *passim*.

[8] Lucas's will is in the Registry of Wills in Somerset House: cited in John W. Clark, ed., *Endowments of the University of Cambridge* (Cambridge, 1904), 165-171.

[9] John Wallis, "Autobiography," *Notes and Records of the Royal Society of London* 1970, 17-46, 27; Babbage, *Passages*, 26.

[10] For disputations, see William Costello, *The Scholastic Curriculum at early seventeenth-century Cambridge* (Cambridge, Mass., 1958), 15. For the curriculum and examinations of Cambridge see also Elisabeth Leedham-Green, *A Concise History of the University of Cambridge* (Cambridge, 1996).

[11] Nicholas Saunderson, *Elements of Algebra*, xv. Gilbert Wakefield, *Memoirs of the Life of Gilbert Wakefield* (London, 1792), 100-101.

[12] For the early history of the Mathematics Tripos see Leedham-Green, *Concise History,* 147–186.

[13] W. W. Rouse Ball, "The Cambridge School of Mathematics", *Mathematical Gazette* 1912, 311–323, 6: 319.

[14] Cited in Leedham-Green, *Concise History*, 152.

[15] *Cambridge University Calendar for the Year 1905–1906* (Cambridge, 1905), 597–601, 725–757.

[16] Stokes to Mary Stokes [née Robinson], 3 February 1857, in Larmor (ed.), *Memoir and Scientific Correspondence*, i, 55–57, 56–57.

[17] For the Statutory Commission see D. A. Winstanley, *Early Victorian Cambridge* (Cambridge, 1955), 314-338; see also *Statutes of the University of Cambridge with the Interpretations of the Chancellor and Some Acts of Parliament Relating to the University* (Cambridge, 1914), 62; Cambridge University Archives, MSS. UA CUR.39.8, f. 17 (1), p. 3; f. 20 and 21.

[18] Gillian Sutherland, "Emily Davies, the Sidgwicks and the Education of Women in Cambridge" in Richard Mason (ed.), *Cambridge Minds* (Cambridge, 1994), 34–47, 34. Newton, *The Correspondence of Isaac Newton* 7 vols (Cambridge, 1959- 77), iii: 280.

[19] Babbage, *Passages*, 19.

[20] Mrs. Laurence Humphry, "Notes and Recollections", in Larmor, *Memoir*, 28.

[21] Richard Marsh, *The Vanity and Danger of Modern Theories: A Sermon Preach'd in Cambridge, 1699.* (Cambridge, 1701).

[22] Newton To Bentley, 10 December 1692. Newton, *Correspondence*, iii, 233.

[23] William Oughtred, *To the English Gentrie, and all Other Studious of the Mathematicks* (London, 1632?), 8.

[24] Whiston cited in Simon Schaffer, "Comets & Idols: Newton's Cosmology and Political Theology," in Paul Theerman and Adele F. Seeff (eds.), *Action and Reaction: Proceedings of a Symposium to Commomoratre the Tercentenary of Newton's Principia* (Newark, 1993), 206-231, 226.

[25] Newton, Yahuda MS 6 f. 11r.

[26] Cited in Sara Genuth, *Comets, Popular Culture, and the Birth of Modern Cosmology* (Princeton, 1997), 8.

[27] Babbage, *Passages*, 292. Pauli cited on http://physics.hallym.ac.kr/reference/physicist/dirac_paul.html. Hawking, *Nutshell*, 24; Michael White and John Gribbin, *Stephen Hawking: A Life in Science* (New York, 1993), 166-167.

[28] Milner, *Life*, ii, 698.

[29] Adrian Desmond, *Huxley: Evolution's High Priest* (London, 1997), 149, 302 n42.

[30] For the ether and metaphysical unity, see Geoffrey Cantor, "The Theological Significance of Ethers," in G. N. Cantor and M. J. S. Hodge (eds.), *Conceptions of Ether: Studies in the History of Ether Theories 1740–1900* (Cambridge, 1981), 135–155; David Wilson, "The Thought of Late Victorian Physicists: Oliver Lodge's Ethereal Body," *Victorian Studies* 1971, 15: 29–48. For Larmor, see especially Andrew Warwick, "The Sturdy Protestants of Science: Larmor, Trouton, and the Earth's Motion Through the Ether," in Jed Z. Buchwald (ed.), *Scientific Practice: Theories and Stories of Doing Physics* (Chicago, 1995), 300–343. Trouton cited in Warwick, "Sturdy Protestants", 326–327.

[31] Paolo Frisi, "Elogio of Newton" in A.R. Hall (ed.), *Isaac Newton: Eighteenth-century Perspectives* (Oxford, 1999), 156; Gribbin and White, *Hawking*, 69; Christopher Lawrence and Steven Shapin, *Science Incarnate: Historical Embodiments of Natural Knowledge* (Chicago, 1998), 4.

[32] Larmor's commitment to plumbing in E. Cunningham, "Sir Joseph Larmor," *DNB*. Dirac's stoicism in Kragh, *Dirac*, 77, 251; Newton's intense study in Steven Shapin, "The Philosopher and the Chicken: On the Dietectics of Disembodied Knowledge," in Lawrence and Shapin, *Science Incarnate*, 21–50, 41; Barrow's rank odour in the *DNB*.

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[33] Larmor's capitulation in the *DNB*; Newton's use of tobacco in Shapin, *Science Incarnate*, 40, Barrow's and Saunderson's offensive habits in *DNB*; Milner's girth and sloth in cited in John Twigg, *A History of Queens' College Cambridge* (Bury St. Edmunds, 1987), 179-182, 181n.

[34] For this reading of the *Principia* see, for example, Margaret Jacob, *The Newtonians and the English Revolution* (Hassocks, Sussex: 1976); Simon Schaffer, "Newtonian Cosmology and the Steady State", (unpublished Ph.D. dissertation, University of Cambridge, 1980). For cometography see Schaffer, "Comets & Idols". For Newton and the wisdom of the ancients see also J.E. McGuire and P.M. Rattansi, "Newton and the Pipes of Pan," *Notes and Records of the Royal Society*, 1966, 21:108-143. Newton and the "world politick" cited in Jacob, *Newtonians*, 43.

[35] http://mmp.maths.org.

[36] James Force, *William Whiston: Honest Newtonian* (Cambridge, 1986), 23-24.

[37] http://www.cfm.brown.edu/people/marmanis/lighthill.html.

[38] James Clerk Maxwell, "Introductory Lecture on Experimental Physics [1871]", in W. D. Niven (ed.), *Scientific Papers of James Clerk Maxwell*, 2 vols., (Cambridge, 1890), ii, 241–255, 244.

[39] William Thomson, "Nineteenth-Century Clouds Over the Dynamical Theory of Heat and Light", *Philosophical Magazine* 1901, 2:1–40.

[40] For Planck and the end of physics, see P. M. Harman, *Energy, Force, and Matter: The Conceptual Development of Nineteenth-Century Physics* (Cambridge, 1982), 153; for Hawking and the end of physics see Hawking, *Brief History* , 156. For Lucas's desire, see appendix to this volume, xxx.