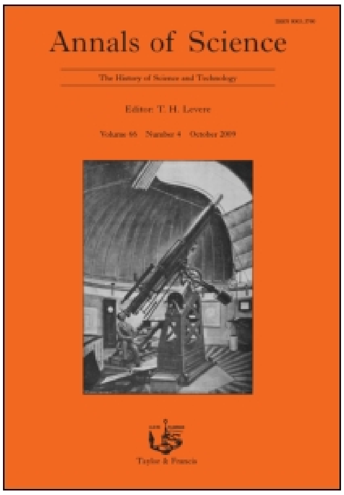

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'A Corrective to the Spirit of too Exclusively Pure Mathematics': Robert Smith (1689–1768) and his Prizes at Cambridge University

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Summary

The Smith's Prize competition was established in Cambridge in 1768 by the will of Robert Smith (1689–1768). By fostering an interest in the study of applied mathematics, the competition contributed towards the success in mathematical physics that was to become the hallmark of Cambridge mathematics during the second half of the nineteenth century. Perceptions of Smith's intentions were to play a part in discussions about the content and balance of the mathematics curriculum, as may be seen in the Airy quotation in the title. In the twentieth century the competition acted to stimulate the formalization of Cambridge postgraduate research in mathematics. Throughout its existence the competition has played a significant role by providing a springboard for graduates considering an academic career and the majority of prize-winners have gone on to become professional mathematicians or physicists. In seeking the reasons behind the competition's success, attention has been paid to the life and work of Robert Smith, the intention behind his bequest, and the history of the competition from its origins until 1940.

Contents

1. Introduction

In 1768 Robert Smith, Master of Trinity College, Cambridge, left a bequest for the founding of two annual prizes for proficiency in mathematics and natural philosophy to be awarded to junior Bachelors of Arts. Smith's bequest was the origin

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of the renowned Smith's Prize competition that still enjoys a high reputation within the Cambridge mathematical community. Up until the last quarter of the nineteenth century it was judged by examination, but in 1883 new regulations were brought in and since 1885 the prizes have been awarded on the strength of an essay on a subject of the candidate's choice.

During the eighteenth century the competition quickly became established as Cambridge's premier mathematical contest, although its reputation was limited to the Cambridge mathematical community. To those outside Cambridge, victory in the mathematical Tripos was still the ultimate achievement. This confusion resulted from a lack of understanding of the nature of the two contests. Although both consisted of sets of examinations, the examinations were of a fundamentally different character. On the one hand, the Tripos was a problem-solving marathon second to none. Its multitude of papers contained more questions than could be solved in the allotted time and success depended more on having the mechanical ability to solve problems as rapidly as possible than on having a clear understanding of the theory. On the other hand, the Smith's Prize examination consisted of only a few papers and was generally aimed at soliciting a more thoughtful or philosophical approach to the questions asked. The level of questioning was of a higher standard and candidates were expected to show insights not required in the Tripos.

As the nineteenth century progressed the competition maintained its reputation in Cambridge as the arbiter of mathematical talent. It gradually became more formalized and its examinations more explicitly tested the creative ability of the candidates. This situation prevailed, more or less unchecked, until the middle of the century when calls for revision of the Tripos were attended by feelings of concern about certain aspects of the competition. There then began a prolonged process of reform that eventually concluded with the changes implemented in 1883. During this period one of the competition's most outspoken champions was George Biddell Airy, the Astronomer Royal, who was especially anxious to preserve its role in supporting the study of applied mathematics.

By fostering an interest in the study of applied mathematics, the competition played a significant part in promoting the remarkable achievements in mathematical physics that characterized Cambridge mathematics during the second half of the nineteenth century. As observed by Edmund Whittaker, among the most brilliant of those responsible for this success were Kelvin, Stokes, Rayleigh, Clerk Maxwell, Lamb, J. J. Thomson, Larmor, and Love.[1] By the time the new regulations for the competition took effect in 1885, three of the four mathematics professorships were held by distinguished applied mathematicians.[2] In addition, two chairs in related subjects had recently been established, the Cavendish Professorship of Experimental Physics (1871) and the Professorship of Mechanism and Applied Mechanics (1875). Although the new professorships were set up to promote practical study, they were founded with a firm underpinning of theoretical mathematics. The professorial lectures were placed under the authority of the Board of Mathematical Studies, and the new professors came via the Mathematical (as opposed to the Natural Sciences)

[1] E. T. Whittaker, *A History of the Theories of Aether and Electricity* (London, 1951), 153. Whittaker actually describes them as belonging to a '"Cambridge school" of natural philosophers', but, as P. M. Harman in *Wranglers and Physicists* (Manchester, 1985), 1, points out, although they engaged in experimentation, it was in mathematical physics that they made their reputations.

[2] The professors were George Gabriel Stokes, John Couch Adams and George Howard Darwin. The pure mathematician Arthur Cayley held the fourth professorship.

Tripos.[3] The first three Cavendish professors,[4] were all Smith's Prize winners, while the first Professor of Mechanism and Applied Mechanics[5] was a third wrangler.[6] But the influence of the examination system could be seen beyond Cambridge, and many senior positions in physics departments in other universities were occupied by high-ranking wranglers and Smith's Prize winners.

The development of mathematical physics in the nineteenth century resulted from a complex web of factors with the Mathematical Tripos as its centre.[7] Closely linked to the Tripos, the Smith's Prize competition formed a critical part of the web and featured significantly in the lives of many Cambridge mathematicians, including all those listed by Whittaker above. From its beginning the competition supported both mathematics and natural philosophy, and over time provided a continuing connection between the two branches of study.

With the change in regulations came a change in status. No longer the archetype of a challenging examination, the competition became instead the harbinger for organized postgraduate research. Cambridge, unlike many of its European counterparts, had no established tradition of training its graduate students. Apart from preparation for fellowship examinations, there was no formal structure for graduates wishing to remain at Cambridge to do research. The introduction of the essay format for the Competition provided a welcome framework in this respect. Moreover, the value of the competition was not eroded with the arrival of the PhD in the 1920s. The PhD took several years to become integrated into the Cambridge system, and once established the competition continued to play an important part by providing a stepping-stone towards it. In its new form the competition was extremely successful, with many of the prize-winning essays providing the basis for research papers of the highest quality.

2. Robert Smith

Robert Smith was christened on 16 October 1689 at Lea in Lincolnshire, and was the son of John Smith (d.1710), rector of Gate Burton, Lincolnshire. His mother, Hannah Smith (d.1719), was the aunt of Roger Cotes (1682–1716). John Smith, who had been educated at Trinity College, Cambridge, was well versed mathematically and in the mid-1790s Cotes was sent to stay with him for mathematical coaching prior to going to St Paul's School. John Smith was a skilful tutor and when Cotes went up to Cambridge in 1699 his mathematical preparation was well beyond what might have been expected.[8]

[3] For an account of the relationship between the Mathematical Tripos and the Natural Sciences Tripos see D. B. Wilson, 'Experimentalists among the mathematicians: Physics in the Cambridge Natural Sciences Tripos, 1851–1900', *Historical Studies in the Physical Sciences*, 12 (1982), 325–71.

[4] James Clerk Maxwell occupied the chair from 1871 until his death in 1879. Maxwell was followed by Lord Rayleigh who retired in 1884, and Rayleigh was followed by J. J. Thomson who occupied the chair until 1918.

[5] James Stuart occupied the chair from 1875 to 1889. He was succeeded by James Alfred Ewing who occupied it from 1889 to 1903.

[6] A wrangler was a Mathematical Tripos graduate with first-class honours.

[7] This and other issues concerned with Cambridge physics in the nineteenth century are widely discussed in Harman (note 1).

[8] R. S. Westfall, *Never at Rest: a Biography of Isaac Newton* (Cambridge, 1980), 703; R. Gowing, *Roger Cotes: Natural Philosopher* (Cambridge 1983), 5–7. J. Edleston (ed.), *Correspondence of Sir Isaac Newton and Professor Cotes* (London 1850), 190–202.

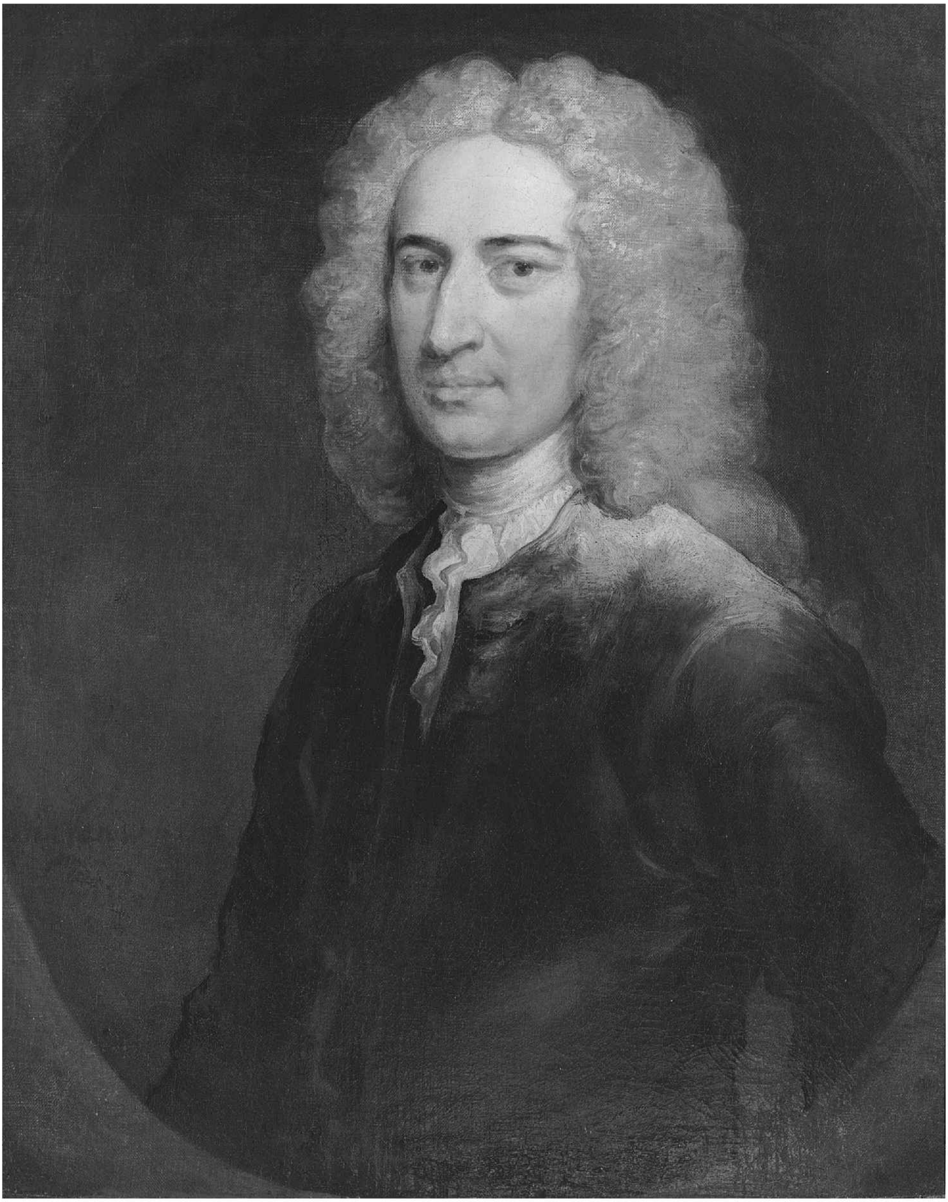

Figure 1. Robert Smith (1689–1768). Portrait by Vanderbank (1730). Reproduced by permission of the Master and Fellows of Trinity College, Cambridge, UK.

Robert Smith entered Trinity College as a pensioner in 1708. He was awarded a scholarship the following year and while an undergraduate he lodged with Cotes. In 1707 Cotes had been elected the first Plumian Professor of Astronomy and Experimental Philosophy, and when Smith arrived in Cambridge Cotes provided work for him as his assistant. In 1711 Smith took his BA and two years later was elected to a fellowship of the College. He held a variety of college posts, and in 1716, on the death of Cotes, was elected to succeed him as Plumian Professor, a position he retained until 1760. In 1742 he was appointed Master of Trinity, and from then on resided in the College lodge until his death in 1768. In 1742–3 he acted as Vice-Chancellor of the University.

During his tenure at Trinity Smith maintained a keen interest in college affairs as well as in the university in general.[9] On the academic side, he lectured on optics and hydrostatics, and, like his cousin, was one of the early supporters of Newtonian philosophy. He edited his cousin's works[10] and wrote two books of his own, one on optics and one on harmonics, both of which enjoyed a high reputation for many years after his death.

Smith's *Optics*,[11] published in 1738 (with an abridged version in 1778) and translated into Dutch, French and German, was essentially the first textbook on the subject and widely read. Voltaire, for example, congratulated Smith upon it,[12] while Desaguliers omitted optics altogether from his own *Course of Experimental Philosophy* in favour of Smith's work.[13] In the nineteenth century, it found favour with both Lord Rayleigh and Hermann von Helmholtz. And Rouse Ball, writing more than 150 years after the book's first publication, considered it to be one of the best textbooks on the subject available.[14] It was especially renowned for promoting the particulate theory of light, as well as other ideas from Newton's *Optics*. In one significant result Smith shows that a certain relationship between the magnification and location of object and image for one lens remains invariant for a system of lenses. This result, later discovered independently by both Lagrange and Helmholtz, is now sometimes referred to as the Smith–Helmholtz formula.[15] The *Optics* also contains detailed descriptions of methods for making optical instruments that were found to be extremely useful and led to increased activity in the manufacture of such instruments.[16] The work concludes with a history of telescopical discoveries. Taken as a whole, the *Optics* shows that Smith had a deep understanding of the theory of the subject, and an extensive knowledge of its history, as well as considerable didactic skill.

Smith's *Harmonics*,[17] which was published in 1749 with a second edition in 1759 and a postscript in 1762, also excited praise. In 1859 T. H. Safford thought it 'an indispensable help in the study of a portion of our subject',[18] while in 1924 R. C. Archibald described it as 'the first English scientific treatment of harmony, a work of

[9] An account of some of Smith's forays into college and university politics is contained in D. A. Winstanley, *The University of Cambridge in the Eighteenth Century* (Cambridge, 1922).

[10] On Cotes's death Smith collected most of Cotes's surviving papers. In 1722 he published Cotes's *In Harmonia Mensurarum et alia opuscula Mathematica* together with some of his own theorems, and in 1738 he published, with notes, Cotes's *Hydrostatical and Pneumatical Lectures*; A. R. Hall and L. Tilling, *The Correspondence of Isaac Newton*, vol. 7 (Cambridge, 1977), 28–9, 98–9; N. Guicciardini, *The Development of Newtonian Calculus in Britain 1700–1800* (Cambridge 1989), 30–1; Gowing (note 8).

[11] R. Smith, *A Compleat System of Optics in Four Books, viz, A Popular, a Mathematical, a Mechanical, and a Philosophical Treatise* (Cambridge, 1738). According to the *Dictionary of National Biography* (1968) this publication earned Smith the nickname of *Old Focus*.

[12] In 1739 Voltaire wrote to Smith 'I have perus'd yr book of optics, I cannot be so mightily pleased with a book, without loving the author, ...', and later made flattering references to it in his 1741 edition of *Elemens de la Philosophie de Newton*; Edleston (note 8), 236–7.

[13] J. T. Desaguliers, *A Course of Experimental Philosophy*, II (London, 1744), vii.

[14] W. W. Rouse Ball, *A History of the Study of Mathematics at Cambridge* (Cambridge, 1889), 91.

[15] Smith (note 11), Book II, ch. 5. The Smith–Helmholtz formula is discussed in detail in Lord Rayleigh, 'Notes Chiefly Historical, on Some Fundamental Propositions in Optics', *Philosophical Magazine*, 21 (1886), 466–76.

[16] R. T. Gunther, *Early Science in Cambridge* (Oxford, 1937), 104.

[17] R. Smith, *The Harmonics, or the Philosophy of Musical Sounds* (Cambridge, 1749).

[18] T. H. Safford, 'Researches in the mathematical theory of music', *Mathematical Monthly*, 1 (1859), 308–12 (311).

high order' discussed in 'a manner attractive even for a reader in the present day'.[19] Smith's primary purpose in writing the *Harmonics* was to provide a description of his 'Theory of Imperfect Consonances'. This was a system for tempering a musical scale, or tuning a keyboard instrument, by making all the consonances as equally harmonious as possible. He constructed a mathematical theory to derive the equal harmonic intervals and validated his results on an organ and a harpsichord. Despite the book's academic success, the system never became popular in practice owing to the difficulty and costs involved in constructing instruments incorporating it.

Smith's career was focused almost exclusively on Cambridge with few exceptions. In 1718 he was elected a Fellow of the Royal Society but he appears not to have played an active role in the Society, although he was a signatory to the Society's certificate of approval given to John Harrison in 1737 in recognition of his work on the chronometer to solve the longitude problem. Smith was also one of the eight commissioners of the Board of Longitude which subsequently voted financial assistance to Harrison.[20] In 1728 Smith was appointed by warrant as *Master of Mechanics* to King George II, the warrant being confirmed on the accession of King George III in 1760.[21] In addition he was also appointed Professor of Astronomy to William, Duke of Cumberland.[22] Both of these appointments involved work at the Kew House Observatory although it is not clear what either entailed.[23] Nevertheless, Smith and Cumberland certainly maintained communication with one another. Smith dedicated both his edition of Cotes's lectures and his *Harmonics* to Cumberland, while in 1740 Cumberland asked Smith to supply him with a sea quadrant and a telescope.[24]

3. Smith's bequest

When Smith died in 1768 his legacy to the university included £3500 of South Sea stock, part of which was specifically allocated for the founding of the prizes.[25] He had stipulated in his will[26] that the interest from this sum was to be divided by the Trustees—the Chancellor or Vice-Chancellor of the University, the Master of Trinity, and the Lucasian, Lowndean and Plumian Professors—into two parts. One part was to be given 'in equal portions as premiums to two Junior Batchelors of Arts' who, having been 'examined by the Trustees, shall appear to them the best proficients in Mathematics and Natural Philosophy', the preference, *ceteris paribus*, being given to candidates from Trinity. The other part was to be used to supplement the salary of

[19] R. C. Archibald, 'Mathematicians and Music', *The American Mathematical Monthly* (January 1924), 1–25 (18–19).

[20] Edmund Halley, who was initially responsible for securing the Royal Society's support for Harrison, was also one of the commissioners, and so too was James Bradley, the Savilian Professor of Astronomy at Oxford. E. G. R. Taylor, *The Mathematical Practitioners of Hanoverian England* 1714–1840 (Cambridge 1966), 20.

[21] The Civil List of King George II for 1747 and 1748 records the payment 'To Rob Smith Master of Mechanics to HIm on 150 p.ann 3 years to Midsm. 1747 450'. The Royal Archives, RA 53922A, 24. The Lord Chamberlain's records list Smith as Professor of Astronomy to the King in 1736. The Royal Archives, LC.5.20 (156).

[22] The Lord Chamberlain's records. The Royal Archives, LC.5.20 (265, 285), LC.5.21 (13, 119, 369).

[23] Taylor (note 20), 144.

[24] Edleston (note 8), 238–9.

[25] In the mid-eighteenth century the profits of the South Sea Company were derived principally from its heavy involvement in the slave trade. See H. Thomas, *The Slave Trade: The History of the Atlantic Slave Trade 1440–1870* (Picador, 1997), ch. 13.

[26] The relevant extract from Smith's will is given in J. W. Clark, *Endowments of the University of Cambridge* (Cambridge, 1904), 94.

the Plumian professor, i.e. Smith's own chair. The will also included provision for 'a handsome dinner once a year' to be enjoyed by the Trustees in recognition of their work in administering the Trust.[27]

Smith left detailed instructions about the administration of the competition. As well as being precise about the financial distribution, he stipulated that printed advertisements announcing the value of the prizes and the time and place of the examinations were to be placed at the gate of every college. But he left no instructions about the actual examining process itself. The Cambridge Tripos system provided a natural model, especially as there were no other comparable prizes in existence in Britain (or, it seems, in Europe). And it appears that from the outset the examination did bear a resemblance, in form if not in content, to the Tripos examination, which by the date of his bequest had become an established and nationally recognized contest, although the rules for governing it were undergoing a process of continuing refinement.[28] Assuming that a Tripos structure was, as seems plausible, Smith's intention, the question remains as to what exactly Smith was hoping to achieve over and above that already accomplished by the Tripos. What does seem likely is that Smith hoped it would stimulate a rise in the level of mathematical knowledge attained by the undergraduates. If this was the case, Smith's hopes were amply fulfilled. His competition soon gained the reputation for being the harder of the two contests, and quickly became established as an important event on the Cambridge mathematical calendar.

However, while there was a broad similarity between the form of the actual examinations, the same was not true of the administrative structures. The two contests were quite different in the way they were run, and it was this difference which largely lay behind the success of Smith's competition.

In the first instance there were the prizes themselves, which had no parallel in the Tripos. In the inaugural year of the competition the prizes were worth £25 each, a sum which would have been attractive to undergraduates, especially at a time when mathematics *per se* offered little by the way of pecuniary advantage. Indeed preparation for the Tripos was in itself an expensive occupation. Apart from the regular expenses involved in being an undergraduate, there was also the cost of private tutoring, or 'coaching' as it became known, which was considered essential for any student nurturing the hope of becoming a wrangler.[29] Smith was noted for his kindness and encouragement to students[30] and perhaps his own experience as an undergraduate made him sympathetic to the idea of a tangible reward for those who had worked hard in their preparation for the Tripos.

Another and perhaps the most important difference between the two contests relates to Smith's nomination of the examiners. In his bequest Smith had stipulated

[27] Details of the dinners are recorded in *Dr Smith's Book* (Cambridge University Archives, Char.I.7), which also lists the toasts to be drunk at the dinners: (1) The King; (2) To the memory of the founder; (3) To the memory of Isaac Newton; (4) Mathematics and natural philosophy; (5) The Board of Longitude; (6) Absent members; (7) The successful candidates; (8) The University.

[28] The Tripos began as an unstructured oral examination which became formalized in about 1710; from 1748 honour-lists were published and in 1753 the division into wranglers and senior optimes was established. For history of the Tripos see J. W. L. Glaisher, 'The Mathematical Tripos', *Proceedings of the London Mathematical Society*, 18 (1886), 4–38; Rouse Ball (note 14) and W. W. Rouse Ball, *Cambridge Papers* (London, 1918), 252–316; Wilson (note 3).

[29] The existence of coaches was reported as early as the end of the seventeenth century. See Rouse Ball (note 28) 1918, 307–10.

[30] For example, Smith provided financial assistance to help Israel Lyons in his mathematical studies, and Lyons showed his appreciation by dedicating his *Treatise on Fluxions* to Smith. Gunther (note 16), 61; I. Lyons, *A Treatise on Fluxions* (London, 1758), iii–v.

that the examiners had to be the Trustees, which in practice usually meant the mathematics professors of the university. This was significant because it eliminated any overlap with the Tripos examiners who were drawn from the pool of college lecturers. Having two completely different sets of examiners meant that the Smith's Prize examination could be used to counterbalance any rumours of partiality that might arise in connection with the Tripos examination. Such rumours resulted from the fact that college lecturers were able to take on additional employment as private tutors, which on occasions led to them being in the dual role of both tutor and examiner for the Tripos.[31] Although it was possible for such a conflict of interest to arise in the Smith's Prize examination,[32] it was rare, and, since the professors were not directly involved in the Tripos examinations, it was more likely for the examiners and candidates never to have met before the examination. The existence of the competition therefore gave candidates in such cases another chance to prove themselves—if not to the world at large, at least to the Cambridge community. In the nineteenth century this was explicitly acknowledged by Babbage, who described the examiners as 'a court of appeal' from the decision of the Tripos examiners.[33]

Another benefit of using the professors as examiners was that it allowed for a broadening of the course of study. The professors were free to set their papers on whatever subject and at whatever level they felt to be appropriate. This meant that they could, and did, set questions that went outside the established academic boundaries set for the Tripos. From the students' point of view, the uncertainty of the questions meant that they could not prepare for the competition in the same way as they could for the more predictable Tripos where speed of pen had ascendancy over original thought. The competition therefore provided a real opportunity for the raising of standards.

A further distinguishing feature of the bequest was Smith's 'preference' for Trinity men. This may have been a straightforward expression of loyalty to his college, it may have been stimulated by a wish to provide an incentive for raising his college's stock in the Tripos lists,[34] or it may have sprung from a desire to guard against any possible bias in favour of St John's. During Smith's Mastership of Trinity there was bitter feeling between the two colleges,[35] and Smith was known not to

[31] A renowned example of this occurred in 1781 when the 1st Smith's Prize was won by the fourth wrangler (Catton), who many believed ought to have been the Senior (in preference to Ainslie). See H. Gunning, *Reminiscences of the University, Town and County of Cambridge*, 2nd edn (London, 1855), 235.

[32] In 1827 Airy had coached three of the four candidates, one of whom, Turner, the 2nd wrangler, won the 1st Smith's Prize, while the fourth candidate, Gordon, the senior wrangler, won the second prize. The situation had arisen because Airy had taken on the pupils prior to his election to the Lucasian chair. He had no more pupils after the summer of 1827. See G. B. Airy, *An Autobiography of Sir George Biddell Airy, KCB*, edited by W. Airy (Cambridge, 1896), 72, 76.

[33] Charles Babbage was Lucasian Professor from 1828 to 1839. See C. Babbage, *Passages from the Life of a Philosopher* (London, 1864), 31–3.

[34] From 1748 to 1768 inclusive, Trinity had one senior wrangler and a total of 14 men placed five or above in the class lists. Caius put in a similar performance with two senior wranglers and 13 men in the top five. But St John's outstripped them both with six senior wranglers and 23 men in the top five. The distribution among the other colleges was fairly even, with most having five or six men in the top group. The next 21 years saw the contest settle down to a straight battle between Trinity and St John's. Trinity had four seniors and 24 men in the top five, and St John's had five seniors and 31 men in the top five. The other colleges were far behind.

[35] This is nicely illustrated in a letter from Smith to Thomas Pelham-Holles, Duke of Newcastle and Chancellor of the University, regarding the idea of Trinity employing a butler from St John's, in which Smith remarks that he is 'not sure whether some of the higher spirits among them [the Fellows] would not sooner quarrel with their bread and butter than receive it from the hands of a Johnian butler'. Winstanley (note 9), 240n.

believe in the impartiality of St John's when it came to moderating the Senate House examination.[36]

One other detail of the wording of Smith's bequest is significant. Smith gave instructions that the prizes were to be awarded to the 'best proficients in Mathematics *and Natural Philosophy*' (emphasis added), natural philosophy being the term used to describe the study of that part of the natural world that could be explored by observation and experiment, the underlying laws of which were sufficiently understood to be amenable to mathematical calculation. The inclusion of natural philosophy thus reflects Smith's own interests as revealed by his publications. However, Smith's reputation in the subject was not only as an academic author; he was an advocate for it too. Unlike some other Cambridge professors of the period (and later), he undertook the lecturing side of his duties diligently.[37] Nevertheless, it would not have been easy for him to promote his subject to undergraduates. As a professor his lectures would have been of an advanced nature and students attending would have been expected to listen passively. By building natural philosophy into his bequest, Smith was providing a way of encouraging its study at undergraduate level. Further evidence of his support for the subject is provided by the fact that the other half of the bequest was left for the benefit of the Plumian professorship. A century later Airy, in a letter to Stokes, described Smith as 'eminently the promoter of Applied Mathematics in his day' and was in little doubt that the prizes 'were partly intended as a corrective to a spirit of too exclusively pure mathematics'.[38] It would seem, therefore, that in explicitly promoting natural philosophy Smith was not simply expressing a personal preference, but he was also acting from a conviction of the need to maintain a place for natural philosophy in undergraduate studies.

4. The value of the Smith's Prizes

When the prizes were first awarded in 1769 they were worth £25 each, at which amount they remained for almost the next 100 years. In 1867 they fell to £23 and in 1915 were still reported to be worth that amount.[39] By 1930 the value had risen to about £30 and by 1940 the value had risen by a further one pound to £31.[40] In 1998 a Smith's Prize winner could expect to receive something in the region of £250. In 1935 Forsyth mentioned that the winners also received a copy of the Glasgow edition of Newton's *Principia* but it is not clear when this practice began.[41]

In 1845 William Thomson (later Lord Kelvin) suggested to his father that his Cambridge debts might be paid for by the Smith's Prize he had just won, although he did add that the money might not be immediately forthcoming. It seems that when

[36] Richard Watson, in his memoirs, recalled, 'I was second wrangler of my year [1759], the leading Moderator [William Abbott] having made a person of his own college and one of his private pupils the first, in direct opposition to the general sense of the examiners in the Senate House who had declared in my favour'. On hearing the news, Smith had told him 'not to be discouraged, for that, when the Johnians had the disposal of the honours, the second wrangler was always looked upon as the first'. R. Watson, *Anecdotes of the Life of Richard Watson, Bishop of Llandaff* (London, 1817), 18.

[37] Gowing (note 8), 138–139.

[38] G. G. Stokes, *Memoir and Scientific Correspondence of the late Sir George Gabriel Stokes, selected and arranged by Joseph Larmor* (Cambridge, 1907), 214.

[39] *Historical Register of the University of Cambridge*, 299.

[40] *Historical Register of the University of Cambridge, Supplement* 1921–1930, 90, and *Supplement* 1931–1940, 74.

[41] The Glasgow edition of the *Principia* was published in 1871 by Robert MacLehose of Glasgow for Sir William Thomson, professor of natural philosophy, and Hugh Blackburn, professor of mathematics, at the University of Glasgow. It was a reprint of the 3rd (1726) edn. A. R. Forsyth, 'Old Tripos Days at Cambridge', *The Mathematical Gazette*, 19 (1935), 162–79 (170).

the university was poor the money was slow in arriving—in 1844 the winners had had to wait some two or three months for their reward—and sometimes it was not paid at all.[42]

However, whatever Smith's intentions might have been with regard to the actual prizes themselves, it is certainly the case that by the middle of the nineteenth century it was in terms of academic prestige that they were most highly valued. By this time it was widely recognized that the standard of examination was superior to that of the Tripos and success in the competition was keenly sought. Generally, all those who competed were leading wranglers and thus already endowed with an academic status recognized well beyond the boundaries of the university. However, although to the outside world a prizeman did not carry the cachet of a senior wrangler, within the confines of the Cambridge mathematical community the honour was seen by many as being the ultimate achievement. William Thomson provides a well-documented example. On 29 January 1845 William Hopkins, the celebrated coach who had prepared Thomson for the Tripos, wrote to Thomson's father:

> It is only want of time that has prevented my writing to you sooner on the gratifying result of the Smith's Prize. It has made us all quite happy again. The examination, as you are probably aware, is altogether of a higher character than that of the Senate-house, being, in fact, intended to furnish a higher test of the merits of the first men. The high philosophical character of your son's mind and acquirements found here much more room for development than in the Senate-house, and the consequence was that he beat his opponent [Stephen Parkinson] with ease—he was the *facile princeps*. None of the four examiners had the smallest hesitation in placing him decidedly first. The result, I assure you, has given great satisfaction to a great number of persons here, as having restored your son to that pre-eminence to which they believe him to be entitled. He has had to contend with a most formidable opponent, with whom he has now fairly divided the highest honours of the University, having himself obtained unquestionably the highest, though not that which, out of the University, confers the most popular reputation.[43]

C. M. Neale who, in 1907, wrote that 'the advanced character [of the Smith's Prize] has led many persons to regard the First Smith's Prizeman as the best Cambridge Mathematician of his year', later endorsed this view.[44]

Furthermore, as indicated in Hopkins's letter, the Smith's Prize examination had the added benefit of giving a second chance to Tripos students who had not acquitted themselves as well as had been expected. Thomson, in being 2nd wrangler, was typical in this respect.[45] H. W. Cookson, Thomson's tutor at Peterhouse, reinforces the point in a letter to Thomson's father:

> In the first place, the decision was *unanimous*. The examiners were Dr. Whewell, Dr. Peacock, Prof. Challis and Mr. Earnshaw,[46] and your son beat all his competitors very decidedly in *all* their papers. In two of them the 'marks' were in the proportion of *three* to *two*. In the other two my informant (one of the four

[42] S. P. Thompson, *The Life of William Thomson, Baron Kelvin of Largs*, 2 vols (London, 1910), I, 118.
[43] Ibid., 107–8.
[44] C. Neale, *The Senior Wranglers of the University of Cambridge from* 1748–1907 (Bury St Edmunds, 1907), 9.
[45] The Senior Wrangler in 1845 was Stephen Parkinson.
[46] Samuel Earnshaw, a celebrated coach and the senior wrangler of 1831, was substituting for the Lucasian Professor, Joshua King.

examiners) told me that your son was decidedly the first, though he did not know the proportion of marks. It is certain, therefore, that in this examination your son has proved himself decidedly superior to the Senior Wrangler [Stephen Parkinson]. It was the unanimous decision of the examiners that he was so. It was also stated by the examiners—though perhaps this is not a matter to be made too public—that the candidates were the best they had ever examined.[47]

Another example is James Clerk Maxwell who, in 1854, was 2nd wrangler but emerged from the Smith's Prize competition equal winner with the senior wrangler, E. J. Routh.[48] The closeness of the contest was evident from the fact that it was only the second occasion on which the two winners had not been ordered, the previous one being in 1805 when the 2nd wrangler, S. H. Christie, joined the senior wrangler Thomas Turton.[49]

The order of merit in the Tripos no longer existed after 1909, and with its demise came a corresponding increase in external recognition for the competition. Fred Hoyle, who was elected to the Plumian chair in 1958, recalled that in 1936, the year he began his research career in Cambridge, his main objective was to win one of the prizes, since 'gaining either a Smith's or a Rayleigh was considered to be almost a guarantee of a post in some university'.[50] But the abolition of the order of merit was not the only reason for the competition's gain in external status. As a result of the change of format the competition was becoming generally recognized as a good indicator of research ability, which, in a burgeoning research climate, was seen as increasingly useful. Added to this, the overall growth of the mathematical profession had led to a wider dispersal of Cambridge graduates throughout the country, many into leading academic positions where they were well placed to promote the significance of the competition.

5. The Smith's Prize examination 1769–1883

For the first one hundred and fifteen years of its existence the competition took the form of an examination which was sat shortly after the Tripos results had been declared, a candidate's suitability for entry customarily being determined by his Tripos position. Since in general only the most distinguished wranglers sat the examination, the numbers entering were usually small, and it was not unknown for the number of candidates to be the same as the number of prizes.[51] Certainly for the first few years of the competition, the number of candidates varied between two and four,[52] and these numbers appear to have stayed fairly constant over time. For example, Babbage examining in the 1820s found that the number of candidates was 'generally three, and rarely above six'.[53]

[47] Thompson (note 42), 106.

[48] E. J. Routh (1831–1907) was later to become a celebrated Cambridge coach and the author of many textbooks.

[49] S. H. Christie became Professor of Mathematics at the Royal Military College, Woolwich, while T. Turton went on to hold the Lucasian chair.

[50] Hoyle won the 1st Smith's Prize in 1938 and remained in Cambridge. F. Hoyle, *Home is Where the Wind Blows* (University Science Books, 1994), 122.

[51] For example, Airy believed that in the year in which he won first prize (1823) there was only one other candidate, Jeffries, who was awarded second prize. Airy (note 32), 40.

[52] The names of the candidates for 1769–75, 1777, are given in a document contained in the Maskelyne Papers held at Cambridge University Library. (The candidates for 1777 are erroneously listed under 1776). The same document also contains mathematical questions and solutions listed for the years 1769 to 1772, but it is not clear whether these are Smith's Prize questions. The author of the document is unknown, although it may be Edward Waring. RGO 4/273.

[53] Babbage (note 33), 32.

In the early days the examination was conducted by the candidates presenting themselves to the examining professors who set problems either viva voce and/or on paper. Since no formal instructions for the examiners existed, each professor had the freedom to set his own standard and to develop his own style of examining. Contemporary evidence suggests that the questions had some similarity to Tripos questions but were of an order of magnitude more difficult. Furthermore, unlike Tripos questions, they were often geared towards evincing an original or creative, as opposed to a rote-learning, approach. During this period it is impossible to know precisely how many of the Trustees were engaged in the examining process but it is reasonable to assume that the actual examiners were those who were mathematically active, although this does not necessarily include all the mathematics professors.

In 1827 Airy, then the Lucasian professor, began the practice of making part of the examination public by publishing his paper in the University Calendar,[54] although questions continued to be dictated to the candidates up until 1830.[55] Airy's example was eventually followed by the other examiners and from 1840 onwards all the papers appeared in the University Calendar. By this time the examination usually consisted of four papers, although on some occasions there were five, each paper being set by a different examiner, and this format remained until the change in the regulations. The published papers also reveal that they were not always set by Trustees. On several occasions substitute examiners were employed. This is not surprising since there was no guarantee that the list of Trustees would contain more than three mathematicians. For example, during the 1840s William Miller,[56] the professor of mineralogy, substituted for the Vice-Chancellor, and Samuel Earnshaw substituted for Joshua King, the Lucasian professor.[57] However, as the case of William Whewell demonstrates—Whewell qualified as a Trustee both as Master of Trinity and as Vice-Chancellor of the University–a non-professorial Trustee could be more than capable of undertaking the duty. There was also nothing in the regulations preventing a Trustee from setting more than one paper, which Airy did on at least one occasion.[58]

One of the original examiners was Edward Waring, Lucasian professor from 1760 to 1798, and who, although not renowned for his lecturing, did take his examining duties seriously.[59] According to Maseres, under Waring the candidates:

> ... were employed from nine o'clock in the morning to ten at night, with the exception of two hours for dinner, and twenty minutes for tea, in answering viva voce, or writing down answers to the Professor's questions, from the first

[54] Airy (note 32), 72, and *Cambridge University Calendar* 1827. Airy's innovation coincided with the change in regulations for the Tripos which prescribed that from that year (1827) onwards all the papers should be printed. 1827 was also the last year in which the Tripos examiners had the power to examine viva voce. Airy's Smith's Prize papers for 1830 and 1831 were also published in *The Mathematical Repository* VI (1835), a journal devoted to mathematical problems and edited by Thomas Leybourn.

[55] Rouse Ball (note 28) 1918, 266.

[56] William Miller (1801–80), who succeeded Whewell as Professor of Mineralogy in 1832, developed a highly acclaimed system of crystallography which was very well adapted to mathematical calculation. He was 5th wrangler in 1826 and published textbooks on hydrostatics and hydrodynamics, and the calculus.

[57] Joshua King (1798–1857), who was senior wrangler and 1st Smith's Prizeman in 1819, and held the Lucasian chair from 1839 to 1849, had a mathematical career distinguished by inactivity. He appears never to have lectured and is described by E. T. Whittaker as 'a man who never wrote anything'. Whittaker (note 1), 153.

[58] Airy (note 32), 79.

[59] According to Dr Parr, Waring's 'profound researches' were not 'adapted to any form of communication by lectures'. J.Gascoigne, *Cambridge in the Age of the Enlightenment* (Cambridge 1989), 180–1.

rudiments of philosophy, to the deepest parts of his own and Sir Isaac Newton's works. Perhaps no part of Europe affords an instance of so severe a process; and there was never any ground for suspecting the Professor of partiality. The zeal and judgement with which he performed this part of his office cannot be obliterated from the memory of those who passed through his fiery ordeal.[60]

Waring, at the age of twenty-five, had been elected by the narrowest of margins to the Lucasian chair, beating Smith's openly preferred candidate, Francis Ludlam,[61] so maybe the ardour with which he examined was fired by his memory of the election. More precise details of his examinations have not come to light, but nevertheless, Maseres's description seems to indicate that Waring adhered to Smith's wishes by examining in both mathematics and natural philosophy.

More is known about the style of examination conducted by Waring's successor to the Lucasian chair, Isaac Milner.[62] Milner, himself senior wrangler (with the distinction *Incomparabilis*) and 1st Smith's Prizeman in 1774, examined regularly from 1798 until his death in 1820. For Milner the examination was not only a means for establishing the supremacy of one student over another but also, since he delivered no lectures as Lucasian professor, an opportunity for meeting and getting to know the candidates.

Edward Alderson, senior wrangler and 1st Smith's Prizeman in 1809, recalled that Milner's examination was 'a very amusing, though laborious day's work' with Milner talking and recounting 'many anecdotes of by-gone days in the University'. John Herschel, the 1813 senior wrangler and 1st Smith's Prizeman, had a rather different experience:

> I was ... far too much frightened at first, and when more at ease, much too intent upon the questions ... (which, however, I well recollect to have been very crabbed ones), to have carried away with me but one sentiment of having got over, for better or for worse a most awful day: and I may say, what few, I believe, who had the happiness of ever being in Dr Milner's company, could do, that I was right glad to be out of it.[63]

George Peacock,[64] the runner-up in Herschel's year, both in the Tripos and the Smith's Prize, appears to have enjoyed the experience rather more, despite not being able to answer several of the questions:

> Dr Milner gave Herschel and myself, questions partly viva voce and partly upon paper. Many of the questions related to practical mechanics, and were such as I could not answer. He gave us an intricate question (a cubic equation with possible roots) to solve by means of a table of logarithms; in which we both failed in obtaining a correct answer; a circumstance which made him very good

[60] F. Maseres, 'Some Account of Doctor Waring', *Monthly Magazine*, 1 (February 1800), 46–9. The quote is attributed to Maseres by Denis Weeks (the article is only signed 'F') who bases his attribution on the article's similarity to another by Maseres which appeared in the *Transactions of the Royal Society*, 70 (Part 1), 221–38. An abridged version of the quote appears in the *Dictionary of National Biography* (1968) and is quoted elsewhere but without attribution. I am grateful to Bob Bruen of MIT for supplying me with this information.

[61] See Winstanley (note 9), 194–8.

[62] M. Milner, *The Life of Isaac Milner* (London 1842).

[63] Ibid., 525.

[64] George Peacock (1791–1858), together with Charles Babbage and John Herschel (1792–1871), was one of the founder members of the Cambridge Analytical Society, and author of the *Treatise of Algebra* published in 1830. He was Lowndean Professor from 1836 to 1858.

> naturedly chuckle and triumph telling us that we had not fared worse than our predecessors in a similar trial. Many of his questions were introductory to very amusing remarks and anecdotes; and I was as much interested and pleased with the whole work of the day, as a person under examination could well be.[65]

On another occasion, Temple Chevallier, the 2nd Smith's Prizeman of 1817, recalled how Milner was prompted by a recent rather unpleasant local robbery to include questions (accompanied by practical demonstrations) on how best to wield a poker in self-defence.[66]

Another of Milner's strategies was to ask candidates for a particular proof and then long before the best candidate could possibly have finished writing ask all the candidates to stop. His rationale was simple. He believed he could judge from the half-finished answers what the completed ones would have been and in this way gain extra time for asking further questions.

By all accounts Milner was a competent and enthusiastic mathematician,[67] added to which he had a very fine and extensive collection of mathematical textbooks, including, rather remarkably in the light of Cambridge's reputation at the time, many by contemporary Continental authors (e.g. Lagrange, Lacroix, Poisson, Monge, Gauss etc.).[68] Yet he made little mark on Cambridge mathematics during his tenure of the Lucasian chair, neither lecturing nor publishing.[69] Although there was not an unbroken tradition of lecturing associated with the Lucasian chair, it is nevertheless perhaps indicative of the status of the competition that Milner, who had lectured diligently in his previous appointment[70] and did not shirk from fulfilling other public duties,[71] appears to have considered the examining sufficient to fulfil his mathematical obligations.

Little is known about the examining of Milner's successors, Robert Woodhouse and Thomas Turton, but the next holder of the Lucasian chair, George Biddell Airy, did more than anyone in the nineteenth century to promote the competition. James Challis,[72] who succeeded Airy as Plumian Professor in 1836, believed his predecessor to be the first to include questions that went beyond the Senate House examination.[73]

Challis may have been mistaken in his attribution of priority (see Maseres's account of Waring's examinations earlier) but since Airy published his papers, the

[65] Milner (note 62), 524–5.
[66] Ibid., 656–8.
[67] See Milner (note 62), and Gascoigne (note 59), 260.
[68] Milner produced an inventory of his books and his entire collection was bequeathed to Queens' College, Cambridge in 1820.
[69] Milner did publish three papers on mathematical subjects earlier in his career, two in 1778 and one in 1779. See Gascoigne (note 59), 277; L. J. M. Coleby, 'Isaac Milner and the Jacksonian Chair of Natural Philosophy', *Annals of Science*, 10 (1954), 234–57 (238n). During the period of Milner's tenure of the Lucasian chair Cambridge did not have a high reputation with regard to mathematical research, although pedagogically it witnessed considerable upheavals resulting from the formation in 1813 of the Analytical Society. Nevertheless, despite his access to Continental methods, Milner appears not to have become involved in the ensuing debates.
[70] Prior to being elected to the Lucasian chair Milner was Jacksonian Professor of Natural Philosophy. See Coleby (note 69). According to Gunning, as Jacksonian professor Milner 'demonstrated an abundance of facts in natural philosophy' which were 'little more than exhibitions of the Magic Lanthorn on a gigantic scale and the guinea and feather experiment [which] always had a rather uncertain ending', although this may be a rather biased account. See Gunning (note 31), 236, and Gascoigne (note 59), 277.
[71] Milner regularly attended meetings of the Board of Longitude. Milner (note 62).
[72] James Challis (1803–82) was Plumian professor from 1836 until his death in 1882. He had a largely undistinguished career, his principal claim to fame being that it was due to his incompetence that John Couch Adams was deprived of the glory of the discovery of Neptune.
[73] *Cambridge University Reporter*, 14 May 1878, 525.

difficulty of his questions is beyond doubt. Airy's paper of 1827 consisted of 24 questions that varied from explicit calculations:

2. By the observations of Captain Sabine, the length of the seconds' pendulum at Sierra Leone, latitude $8^{\circ}29'28''$, is 39,01997 inches: that at Drontheim, latitude $60^{\circ}25'54''$, is 39,17456 inches. Calculate from these data the ellipticity of the Earth.

to explanations,

5. Explain why the gnomon of a dial must be parallel to the Earth's axis.

and formal proofs:

15. Prove the process for taking an integral between limits; and find the value of $\int_x \frac{1}{x^5+1}$ between the limits $x = 0$, $x = 1$.[74]

On occasions the professors introduced questions that related to the results of relatively recent research. Sir George Stokes, who was elected to the Lucasian chair in 1849, included in the 1854 examination (the one successfully sat by Clerk Maxwell), the result in potential theory now known as 'Stokes' Theorem'. Rather astonishingly, it was the theorem's first appearance in print.[75] In 1871 Arthur Cayley, Sadleirian Professor from 1863 until his death in 1895, included a question on caustics which was directly connected to a theorem he had first published in 1857; while in 1879 he set a question on Newton's method which was the basis for a paper he published later in the same year.[76]

It was not unusual for the examinations to be conducted in the professors' own homes, but sometimes the candidates found the surroundings altogether too awesome to cope with. And it was not only the candidates who had difficulties. Stokes clearly found his examiner's role hard going, as his daughter described:

> The days of the Smith's Prize and Bell Scholarship Examinations[77] were always marked days with us; as the house was turned upside down; we lunched in the drawing room, and the dining-room mahogany supported the elbows of those who were examined. If they were in awe of my father during their papers, he was quite afraid of them at lunch. He considered it a part of his duty to help to relax their mental strain, and used to lament that he found it so difficult to entertain

[74] The notation is Airy's own.

[75] Although Stokes published the theorem in 1854, it was certainly known to William Thomson in 1850. For a history of the theorem see J. J. Cross, 'Integral Theorems in Cambridge mathematical physics', in Harman (note 1), 112–48 (143–5). See also G. G. Stokes, *Mathematical and Physical Papers*, vol. 5 (Cambridge, 1905), 309–68 (320–1) which includes all Stokes's Smith's Prize examination papers; and D.B Wilson, *The Correspondence between Sir George Gabriel Stokes and Sir William Thomson, Baron Kelvin of Largs*, vol. 2 [1870–1901] (Cambridge, 1990), 96–7.

[76] A. Cayley, 'Solutions of a Smith's Prize Paper for 1871', *Messenger of Mathematics*, 1 (1872), 37–47 (43); 'Application of the Newton–Fourier method to an imaginary root of an equation', *Quarterly Journal of Pure and Applied Mathematics*, 16 (1879), 179–85. The Sadleirian professor was a natural choice for an examiner but since the chair was only founded in 1863 it was not on the list of original Trustees. In 1867, the year after Whewell's death, the examining duties of the Master of Trinity were delegated to Cayley, and in the following year the number of Trustees was increased to include the Sadleirian professor.

[77] The Bell Scholarships were founded in 1810 to give financial assistance to the sons of clergy who would otherwise not have been able to attend the university. *Historical Register of the University of Cambridge*, 265.

> them and did not know what to say. It once happened that during the recreation interval in the garden after lunch two candidates ran away. It was particularly unfortunate, as one of them had done rather well. The event was long spoken of in the family with bated breath, and afterwards the garden gate was kept locked on these occasions.[78]

On the other hand, Cayley went to considerable trouble to make the environment for the examination as congenial as possible and had little difficulty in doing so. Karl Pearson, who was 3rd wrangler in 1879, clearly enjoyed Cayley's examination, notwithstanding his lack of success:

> The next day we went to Cayley's. His first words were, 'Throw off your gowns, gentlemen, you will work more easily without them' and accordingly they were dropped in a heap in a corner of the room, and we set to work unencumbered. Of course I knew nothing of the topics of Cayley's paper. My chance of scoring marks in the Tripos had depended only on my applied mathematics, and my pure mathematics were but sufficient to help in the former branch. But I took things leisurely, as if nothing depended on speed, and worked as one might work in solving crossword puzzles on a train journey. Cayley did not appear at lunch; sandwiches, biscuits and other light refreshments were brought up on a tray, accompanied by a decanter of excellent port wine; Cayley had not spared his cellar. After sampling a glass, I tried to persuade my co-examinees to do so likewise; two, I think, took a driblet, but the future Smith's Prizeman [M. J. M. Hill or A. J. Wallis] speaking from his conscience refused—he was true to what he had originally said in our first term. He had come to Cambridge for examination ends; perhaps he thought I was tempting him to drop the prize already well within his grasp. Back we went to our writing, I feeling the better for Cayley's port, and the others satisfied in their consciences that they had done the right thing under examination stress. Cayley evidently did not think good port at all incompatible with the discussion of invariants or higher algebra. A few days later a friend of Cayley's told me that Cayley had remarked that there was only one man who had appeared to enjoy his paper—it was the one man who had thoroughly enjoyed his port. Somehow that commendation was more to me than if I had won a Smith's Prize or I had gratified Routh or my college in being senior [wrangler].[79]

Indeed for Pearson, by a strange twist of fate, the Smith's Prize examination provided a turning point in his career. In one of his solutions he gave a proof which the examiner, Isaac Todhunter substituting for James Challis, recognized as being better than the accepted one.[80] It was to prove a fortuitous conjunction. Several years later, as a result of circumstances connected with Todhunter's publication of Pearson's solution, Todhunter provided Pearson with an introduction to the Cambridge University Press, an organization which was to play a significant part in his life.[81]

In 1882 Challis, who had examined for over forty years, died before the papers for the following year had been set, and William Thomson, who had held the chair of

[78] Stokes (note 38), 11.

[79] K. Pearson, 'Old Tripos Days at Cambridge Seen from Another Viewpoint', *The Mathematical Gazette* 20 (1936), 27–36 (32–3).

[80] Isaac Todhunter (1820–84), senior wrangler and 1st Smith's Prizeman of 1848, was a private coach and a college lecturer at St John's. He was a prolific author of textbooks.

[81] Pearson (note 79). Pearson also completed the second volume of Todhunter's history of elasticity, which was published in 1893.

natural philosophy at Glasgow since 1846, was asked to substitute for him as an examiner.[82] Thomson asked Stokes, who had been an examiner for more than thirty years, what was involved. Stokes's reply is informative:

> The examination is to begin on Monday the 29th twenty-ninth, [*sic*] and lasts 4 days; the first day we have a paper of essahys [*sic*] to which each examiner usually contributes one. If you would send in say two or three proposals, indicating the order of your choice, it would help us. We have been in the habit of setting 4 questions for essays. Tuesday your paper comes on. We used never to consult beforehand, and each had more or less a style of his own, so that the subjects were fairly represented among us. Latterly, only 3 or 4 yoers, [*sic*] we have looked at each other's papers beforehand, so as to make a better distribution of the subjects. If you would permit us to see your paper before it is set, it might help us in distributing the subjects better that we might otherwise have done.[83]

Having prepared his paper, Thomson sent it to Stokes, together with the following list of possible essay subjects:[84]

1. On Capillary Attraction
2. On the direction of the Vibrations in plane polarized light
3. On Vortex Motion in ⟨the⟩ an inviscid incompressible homogeneous liquid.
4. On cyclic [or 'many valued'] functions, as illustrated in vortex motion, and in the field of force of an electromagnet.
5. On the Dissipation of Energy from the Solar System.
6. On reversibility in abstract dynamics, and in nature.

The published paper shows that Thomson's first choice was the one used, despite it having been set before. In fact the first three of Thomson's suggested topics had appeared in previous papers (in 1875, 1869 and 1881 respectively). Thus it is clear that the examiners felt under no obligation to construct new subjects for examination each year. Apart from Stokes and Thomson, the other examiners in 1883 were Adams and Cayley, and the final paper was as follows:

1. The two kinds of quartic curves in space.
2. The theory and construction of the Achromatic Object Glass, the modes of testing it, and the choice of form.
3. Capillary attraction.
4. The equilibrium theory of the tides.

In the event, the paper, or the last three topics at least, produced disappointing results. According to Thomson, the essays on Achromatism and capillary attraction were '*all* very poor', while those on tides deserved 'negative rather than positive credit'.[85] He considered the mathematical work badly done and thought the essays would have been improved had they made less attempt to incorporate mathematical analysis. In fact the calibre of the candidates was rather high—they included H. H. Turner who went on to become Savilian professor of astronomy at Oxford and F. S. Carey who became professor of mathematics at Liverpool—which suggests that their poor performance stemmed more from a lack of experience in essay writing than

82 Letter to Sir George Stokes, 7 January 1883. Wilson (note 75), 536–7.
83 Letter to William Thomson, 9 January 1883. Ibid., 538.
84 Letter to Sir George Stokes, 21 January 1883. Ibid., 541–2.
85 Letters to Sir George Stokes, 4 and 5 February 1883, Ibid., 545–7.

a lack of mathematical ability. The candidates had had little opportunity, or indeed incentive, to practise their writing skills. It is of interest, therefore, to note that at the end of that year an essay paper was included in Part III of the Tripos. Candidates were asked to choose two topics from a choice of eight. With six of them being on applied subjects, the ratio was identical to that in the Smith's Prize examination of the same year.

Apart from revealing the kind of topics deemed worthy of examination, this exchange between Stokes and Thomson also shows that at the beginning of 1883, despite the growing prestige attached to the prizes, there was still no cohesive framework for the examining process actually in place. But the situation was on the threshold of change.

Clearly, there were shortcomings in a system that relied on a spirit of cooperation between the professors, their individual academic inclinations, and their level of interest in the competition itself. These limitations were gradually recognized and by the middle of the nineteenth century voices of dissent had begun to be heard. This period was also a time of continuing debate with regard to the organization of the Tripos, and it was within this context that the structure of the competition really began to come under scrutiny. After prolonged discussions the regulations were eventually changed, and 1883 was the last year in which the prizes were awarded on the basis of an examination.

6. Towards a change in the regulations 1848–75

The new regulations that came into force in 1883 were incorporated as part of a general package of Tripos reform. Although they were passed in 1878, ideas about reform had been under debate for some twenty years, and really stemmed back a further twenty years to a period when increasing dissatisfaction with the Tripos system resulted in new regulations and the creation in 1848 of the Board of Mathematical Studies.[86] These early reforms explicitly reflect the symbiosis that had developed between the two sets of examinations, and for the next thirty years the question over the precise role of the competition with respect to the Tripos was hotly debated. A conflict developed between supporters of pure and applied mathematics, with both sides using Smith's will to defend their position. In addition, there was a clear division between those anxious for change, and those motivated by a desire to maintain the status quo.

In the 1830s one of the effects of the Smith's Prize examination had been to open the way for the introduction of new subjects into the examination system as a whole. As a result of Airy's influence, questions on subjects such as definite integrals, Laplace's coefficients, electricity, magnetism, and heat were included in the Smith's Prize examination, all subjects which shortly afterwards were to find their way into the Senate House examination. But while there were obvious benefits in expanding the mathematical horizons of the undergraduates, there were also costs.

In the 1840s it was recognized that the enormous number of subjects on which a student could be examined for the Tripos far exceeded what could reasonably be expected. But, since the content of the examinations was essentially unregulated—and frequently idiosyncratic since examiners often took the opportunity to advance their preferred area of study—and there was no formal structure in place for amending the situation, change was slow. The process was further hampered by the fact that some

[86] For a more detailed account of the Tripos reforms see Wilson (note 3).

of the ideas of the key reformer and prime mover behind the creation of the Board of Mathematical Studies, William Whewell, took time to be accepted.[87] In particular, Whewell argued against what he saw as the increasing proliferation of analysis at the expense of geometry and the neglect of Newtonian mathematics. Although he was responsible for introducing Continental methods into mechanics at Cambridge, he became increasingly worried about the pursuit of abstract analysis for its own sake. Like Airy, with whom he maintained a close association, he was a fundamental believer in the supremacy of applied mathematics.

When the Board of Mathematical Studies was established, it was made up of the mathematics professors, and the examiners and moderators for the current year and the two preceding years. Since its membership covered all aspects of the examining process it was clearly designed to provide a reflection of the prevailing mathematical emphasis. It is sufficient to note therefore that its initial composition included only one pure mathematician, the Lowndean Professor, George Peacock.

The Board's remit was to report on the past and present state of mathematical studies and to make suggestions for the future. More specifically, it was charged with encouraging attendance at lectures of the mathematics professors and trying to secure a correspondence between the lectures and the examinations of the university. Although Airy had generated considerable undergraduate interest in his own (primarily experimental) lectures, the recent increase in subjects for the Tripos had meant that there had been an almost complete dropping away of attendance at professorial lectures. The general undergraduate experience had become an endless grind of Tripos preparation far removed from any stimulus provided by exposure to recent professorial research. As a result, the competition was left as the only real means of contact between professors and undergraduates. From the candidates' point of view this contact gave them the chance to demonstrate their abilities and enhance their career prospects. From the professors' point of view, examining for the competition kept them in touch with the academic standard of the (best) undergraduates as well as the content of undergraduate studies.

The Board's report of 1849 recommended the exclusion from the Tripos of several of the subjects only recently introduced, including the mathematical theories of heat, electricity, and magnetism. In the following year they recommended the dropping of elliptic integrals, Laplace's coefficients, and capillary attraction, as well as imposing certain limitations on questions concerning the lunar and planetary theories, although their recommendations were really only a formality since, in practice, these reductions had already been made. The Smith's Prize examiners were under no obligation to mimic the changes in their examinations but in practice they did so. For example, between 1849 and 1852 there were no questions on heat or electricity, and only Whewell persisted each year in asking a question on magnetism. Nevertheless, the abundance of questions on optics and planetary theory meant that there remained plenty of opportunity for candidates to display proficiency in applied mathematics.[88]

[87] William Whewell (1794–1866), who was 2nd wrangler and 2nd Smith's prizeman in 1816, and Master of Trinity from 1841 until his death in 1866, campaigned tirelessly for reform of the Tripos. He was anxious to introduce stability into both the curriculum and the examining process, and in particular thought it essential for there to be a close relationship between what was being taught (both at collegiate and at professorial level) and what was being examined. For a detailed account of Whewell's role in the reforms, see H. W. Becher, 'William Whewell and Cambridge Mathematics', *Historical Studies in the Physical Sciences*, 11 (1980), 1–48.

[88] Challis, in a testimonial for P. G. Tait dated 1853, singles out for praise the mastery of applied mathematics demonstrated by Tait during the Smith's Prize examination in 1852. *Testimonials in favour of PG Tait*, SD 3847, Edinburgh University Library.

However, by the 1860s, partly as a result of the earlier changes, new problems had emerged. By then it had become apparent that certain important branches of mathematics and mathematical physics were not included in the studies of the university because they had been excluded from the Tripos.[89] This realization resulted in further change to the Tripos regulations that extended the areas of study and which eventually came into effect in 1873. Under these reforms more subjects were included but candidates had some flexibility in the subjects they could choose to study. The idea was that the best students would study fewer subjects but they would study them to a higher level, whereas the weaker ones could get by with less detailed knowledge spread over a wider range. These alterations had the effect of sanctioning the introduction into the examination of a wider range of questions in experimental and theoretical physics. However, the scheme worked against the effectiveness of the Smith's Prize competition since it left little to distinguish between the two sets of examinations. In any event, the scheme was not a success because it turned out that the best way of optimizing marks was to have a superficial knowledge of all subjects rather than a real proficiency in a few of the higher ones. It was in an endeavour to compensate for this unforeseen outcome that further revisions were made in 1878.

Alongside the discussions over the reform of the Tripos was a parallel debate over the role of the Smith's Prize competition. This also led to calls for change. One change that was implemented in 1868, and was without controversy, was the abolition of the clause relating to the preference to candidates from Trinity in case of equality. It appears that the clause was never invoked and presumably was seen as superfluous.[90] At the same time the Sadleirian Professor was made an ex-officio Trustee, and the Master of Trinity, although remaining a Trustee, was exempted from having to take part in the examination. In addition, the Vice-Chancellor was given the power to appoint examiners in cases where the ex-officio examiners were unable to perform the task. Other matters were more contentious.

The nature and timing of the examinations had led to a strong expectation in many quarters that the results in one contest should be mirrored in the other. Although many recognized the value of the competition as a safeguard against partiality, there were those who believed that any discrepancy between the two results could be due only to an error of judgement by one of the sets of examiners. Thus even within Cambridge there was confusion over the role of the competition. Matters came to a head in 1857 when William Hopkins, having analysed four instances in which the Smith's Prize examiners had reversed the order of merit settled by the Tripos examiners, pronounced that three out of the four should not have had their positions disturbed. His findings aroused considerable disquiet.[91]

Prompted into action, the Council of Senate's solution was to recommend that only one Prize should be offered and that it should be awarded 'to the Bachelor of Arts, under the standing of the Master of Arts, who shall compose the best essay on a given subject in mathematics or natural philosophy'.[92] This was a radical suggestion that would have completely changed the nature of the competition, but it was not

[89] In 1869 Airy gave a course of lectures on magnetism with a view to introducing the subject into the studies of the university. The lectures attracted a large audience and Airy developed them into his *Treatise on Magnetism Designed for the Use of Students in the University*, which was published in 1870.

[90] While the clause existed, Trinity and St John's shared almost equal honours in the competition, with 65 and 59 prize-winners respectively, and the other colleges sharing the remaining 77 prizes between them.

[91] Letter from G. B. Airy to the Vice-Chancellor dated 5 December 1857, and letter from W. Hopkins to the Vice-Chancellor dated 9 December 1857. Cambridge Papers GF109.

[92] The report of the Council of the Senate, 4 December 1857, University Grace Book (270(a)).

properly thought out. If the essays had to be original, then it was hard to imagine that anyone having just completed the Tripos would be in a position to enter, while if there were no constraint of originality, then they would be hard to judge. Another suggestion was that the prizes should be awarded on the results of the Tripos.

One of the principal objectors to both these ideas was Airy. Although Airy had left Cambridge in 1835, he still maintained a keen interest in the affairs of the university, and was, with his own experience as a former prize-winner and subsequently as an examiner, well qualified to comment. In a letter to the Vice-Chancellor he argued for the continuance of the current system, protesting vehemently against Hopkins' method of criticism, the effect of which he saw as destroying all independence of the examiners.[93] Not only did Airy see the two sets of examinations as being of quite different kinds, and therefore equally worthy of their place in the system, but he also believed an essay prize to be neither feasible nor desirable. As he pointed out, the problem was one of ignorance. The Smith's Prize examination was not simply a harder version of the Tripos, it was altogether different, being neither trammelled by university regulations nor aimed at the same constituency. Although Hopkins vigorously defended his methods, giving full support to the idea of an essay Prize,[94] Airy's arguments were convincing.

The issue came up for discussion again in the 1860s, by which time the competition was seen by many to be a rival to the Tripos examination, and it was suggested that its management should be handed over to the Senate House examiners, either wholly or in part. Once again Airy became involved. In February 1868 Stokes wrote to him requesting an opinion on the issue. Airy totally rejected the idea, replying:

> I am not acquainted with the history of the foundation of the Prizes but I remark that Dr Smith, the author of the *Harmonics* and *Optics*, was eminently the promoter of Applied Mathematics in his day. Looking at this, and the title (derived, I believe, from his will) which they have always borne, I scarcely doubt that they were partly intended as a corrective to a spirit of too exclusively pure mathematics.
>
> ... There is no accuracy of teaching like that of Cambridge: and in the applied sciences that are really taken up there, of which I would particularly mention Astronomy, the education is complete and excellent. But with this, there is an excessively strong tendency to those mathematical subjects which are pursued in the closet, without the effort of looking into the scientific world to see what is wanted there; and common circumstances produce a common effect on many men till it becomes a peculiarity of the University.
>
> The question then arises, how can this (considered as a fault) be corrected? I have often wished that we could have in our examiners an element foreign to the University. But looking to the extreme difficulty of this, I am very glad to accept the next available aid: namely the assistance of the Professors of the University, whose position makes them responsible to the world, and whose pursuits are connected with science exterior to the University.
>
> ... You mention as one of the causes of unfriendly feeling to the Smith's Prize Institution the idea that its examination is a sort of rival to the Senate House Examination. Certainly it is so, and I hope it ever will be so. Its function would

93 Airy (note 91).
94 Hopkins (note 91).

> cease if it were not so. The mere 50 for two prizes is a trifle: it is nothing in comparison with the prizes of fellowships which are waiting for the 1st and 2nd wranglers: the whole foundation would be nugatory if the examination were not independent, and therefore necessarily a rival.[95]

For Airy the independence of the examinations was essential, and to this end he believed the rivalry to be a force for good. The involvement of the professors gave the competition its validity. It not only made for more mathematically challenging examinations, but also, and more importantly, provided a conduit through which to bring the scientific world outside Cambridge into the realm of the undergraduate. Before he had left Cambridge, Airy had used both lectures and examinations as ways of extending the knowledge bounds of students, and he was keen that such a practice should continue. As a leading exponent of 'mixed mathematics',[96] that is the mathematics of physical subjects such as astronomy, hydrodynamics, mechanics, optics, and planetary theory, he empathized with Smith, and in his ten years as an examiner for the prizes, he had remained true to his own interpretation of Smith's objectives. His examination papers, although containing questions on pure mathematics, were clearly weighted in favour of applied, and he was determined that such a practice should continue. Added to this, his experience as a Tripos examiner had left him convinced of the need for a more intellectually challenging test such as that provided by the Smith's Prize examination.

Although Airy's views on Smith's intentions were retrospective and could be interpreted as partisan, the evidence in support of applied mathematics provided by Smith's academic interests gave Airy a forceful weapon which he used to good advantage. His argument was persuasive and the competition survived, temporarily at least, unchanged.

However, in 1873 Isaac Todhunter published an essay on the Mathematical Tripos which contained almost the complete antithesis to Airy's point of view.[97] Todhunter argued forcefully for abolition of the Smith's Prizes Examinations, declaring that Smith's benevolent intention was now 'productive of a decided balance of mischief and misery'.[98] He drew on Hopkins's earlier testimony and was particularly censorious about the actual examination process. Making a comparison with the Tripos Examination he pointed out that the Smith's Prizes Examination papers were prepared over a very short period of time—a matter of days as opposed to months—and with little or no consultation. He also drew attention to the fact that there was no procedure for ensuring that the Smith's Prizes papers were all of an equivalent standard even though they each accounted equally towards the final result. Furthermore, he was not convinced that the professors were necessarily appropriate examiners.

Todhunter's views revealed that there was still a considerable feeling of disquiet about the form of the competition. In 1875 the voices of dissent were heard more loudly when, triggered by the lack of a senior wrangler among the 1874 and 1875 prize-winners, the question of discrepancy between the Smith's Prize and the Tripos

95 Letter dated 22 February 1868. Stokes (note 38), 213–15.

96 Airy's *Mathematical Tracts*, first published in 1826, and updated and expanded at regular intervals, was the quintessential textbook of 'mixed mathematics'. It became essential reading for the Tripos, and its contents helped direct the course of the Senate House examination.

97 I. Todhunter, *Conflict of Studies* (London, 1873), 193–242 (226–36).

98 Ibid., 236.

examination results was once again aired in the public arena. Several mathematicians contributed to the debate, including Ferrers,[99] Besant,[100] Cayley and, of course, Airy.

7. The debate continues 1875–8

The renewed interest was prompted by the 1873 change in the Tripos regulations, which had increased the number of subjects examinable, and which had become to be seen as undermining the purpose of the Smith's Prize examination. Comparisons drawn between the eighteen papers of the Tripos and the four papers of the Smith's Prize for 1875 were interpreted as revealing the latter to be under strength in the area of natural philosophy. Ferrers compiled a list of the subjects he considered to be lacking.[101] These included the 9th and 11th sections of Newton, planetary theory, rigid dynamics, attractions, precession and nutation, sound, the vibrations of strings and bars, and the theory of elastic solids. Airy, in a manner reminiscent of his response of seven years earlier, referred to the 'pernicious preponderance of a class of pure mathematics'.[102] He reiterated his belief that Smith's purpose was the promotion of 'Physical (not abstract) Mathematics', and suggested the introduction of assessors. By this he meant men who were, if possible, former members of the university and 'officially acquainted with current Physical Science'. But the feeling was not all one-sided and there were those, such as Besant and Cayley, who were satisfied with the system as it stood.

Cayley, who was responsible for many of the questions on pure mathematics, took great exception to Airy's views, disagreeing with him on almost every point, and in particular with Airy's interpretation of Smith's objectives.[103] In his own reading of Smith's will Cayley could find no evidence to support Airy's opinion that Smith had intended to favour natural philosophy over pure mathematics. In the light of Smith's academic reputation Airy's position was not unreasonable but the fact that Cayley returned to the original source to support his argument underlines the importance of the debate from his perspective. However, unlike Airy, Cayley had no additional evidence to strengthen his argument for the contents of the examination. Furthermore, not only was he was up against Airy but also, as the only pure mathematician amongst the mathematics professors (the others included Stokes, Adams, and Maxwell), he could not count on much support. It was therefore understandable that he tried to counter Airy as forcefully as he could.

No immediate revisions were made, but in May 1877 a Syndicate was appointed to 'consider the Higher Mathematical Studies and Examinations of the University'. Although the primary task of the Syndicate was to consider the plan of the Tripos examination, the competition also came under their review. In July 1877 two members of the Syndicate, Routh and Besant, circulated a paper to other members suggesting that the prizes should be given to the two wranglers who most distinguished themselves in Part III of the Tripos.[104] They also suggested that one prize might be given to the best proficient in mathematics and one to the best proficient in natural

[99] Norman Ferrers (1829–1903), who was senior wrangler and 1st Smith's Prizeman in 1851, was a lecturer at Gonville and Caius. He became Master of Gonville and Caius and was a moderator for the Tripos on more occasions (11) than anyone else.

[100] William Besant (1828–1917), who was senior wrangler and 1st Smith's Prizeman in 1850, was a popular private coach and a lecturer at St John's.

[101] Cambridge Papers, GF109.

[102] Letter to N. M. Ferrers dated 25 February 1875. RGO 6/820 (412).

[103] Cambridge Papers, GF109.

[104] Minutes of the Mathematical Studies Syndicate, CUR 28.6.2.

philosophy, an idea which allowed for the possibility of the same person winning both prizes. However, their suggestions gained little support as the majority of the Syndicate were moving towards the idea of eliminating examinations altogether from the competition and awarding the prizes on the basis of essays.

The idea of using essays instead of examinations had been in the air for some time. As mentioned earlier, a proposal to this effect was originally put forward in 1857. Thus it was not surprising when, within the context of the 1868 discussions, an attenuated version—the idea of whether essays should replace some (as opposed to all) of the questions—was put forward. This proposal was well received. Even Airy raised little objection and suggested using the Adams Prize[105]—a biannual prize which was first awarded in 1850 and required entrants to submit an essay on a set subject—as a guide.

During the period just prior to these discussions the examination papers each contained between fifteen and twenty questions, most of which required exposition as well as calculation, although on occasions essay-type questions had been set. For example, as early as 1850, Peacock had included a question which asked candidates to write short dissertations on three set subjects,[106] in 1860 Stokes did likewise,[107] while in 1868 Cayley had included a question which asked for a single dissertation but with the content clearly defined.[108] Thus it was not the actual inclusion of essay questions that was under discussion but rather whether the inclusion of such questions should in some way be formalized. The Trustees found in the affirmative and in February 1868, after the competition had taken place for that year, they stated that they were 'prepared to adopt measures for giving the examination a different character from that of the Senate House by setting up one or more papers containing questions, the answers of which naturally partake of the character of essays'.[109]

This was fully implemented in 1869 when one of the four papers was devoted entirely to dissertation topics. Candidates were invited to choose no more than two from the following eight:

1. The partition of numbers.
2. The nature of imaginary quantities, and the logical character of mathematical processes in which they are employed.
3. The calculation of maxima and minima, and criteria for distinguishing between a maximum and a minimum. Discuss (1) the method of finding the maximum and minimum values of a function of one or more variables; (2) the method of finding functions possessing maximum or minimum properties.
4. The integration of partial differential equations of the first order, both of the first and of higher degrees, with geometrical illustrations.

[105] G. G. Stokes (note 38), 215. The Adams Prize was founded to commemorate Adams's deductive discovery of Neptune and it is open to any graduate of the university. Although similar competitions had been in existence for some time on the Continent, the Adams Prize was the first of its type in England.

[106] The topics were: (1) The foundations of statics; (2) On the relations of zero and infinity; (3) On the methods used for determining the masses of the planets.

[107] The topics were: (1) The transformation of multiple integrals; (2) On the methods which have been employed for determining the density of the earth; (3) On the evidence in favour of the optical theory of transversal vibrations.

[108] The full question read: 'Write a short dissertation on the transformation of co-ordinates (rectangular, in a spare of three dimensions): and in particular explain under what restriction it is true that two sets of rectangular axes about the same origin may be made to coincide by means of a rotation of either set about a certain axis, and from the formulae of transformation obtain expressions for the position of this axis and the amount of rotation.'

[109] *Dr Smith's Book* (note 27).

5. Cubic curves, or any particular branch of their theory.
6. The construction of optical instruments for magnifying objects and conditions of distinct vision.
7. The attraction of a homogeneous ellipsoid, the law of attraction being that of the inverse square of the distance.
8. The laws of the interference of polarized light, their establishment by experiment, and their comprehension in a general theory.

The questions therefore covered a fairly broad spectrum and candidates could choose to limit themselves to either pure or applied topics. This was presumably seen to be too flexible as the following year the format of the paper changed. It contained only four questions:

1. The theory of the change of the independent variables in multiple integrals.
2. Developable surfaces.
3. The general laws of the motions of a dynamical system, without friction, slightly disturbed from a position of stable equilibrium. Discuss fully the example of a uniform flexible and inextensible string suspended from one extremity and moving in one plane, including in your discussion the case in which the point of suspension is at an infinite distance.
4. The derivation of the laws of the steady motion of incompressible and compressible fluids from the general hydrodynamical equations. Discuss the example of such motion in each kind of fluid.

Each one was set by a different examiner, and candidates were expected to attempt all four. There were no written instructions with regard to the form of the answer, and while some of the questions were quite explicit in terms of what they required, others appeared almost open-ended. However, between 1873 and 1875 Cayley published specimen solutions to some of his questions thus making it possible to get an idea of what he expected.[110] This was not the first time that Cayley had published solutions: he had been doing so for his problem papers since 1867.[111] However, his first essay-question solution was prefaced by remarks about unsatisfactory answers, suggesting that on this occasion he had been prompted into print by a disappointing response to the question. Nevertheless, it appears that in general the essay paper was deemed a success since it then remained in the examination with the format unchanged.

There was also another development taking place within the university that was pertinent with regard to the use of essays in the competition. In 1872 Trinity College introduced dissertations into college fellowship elections. Candidates were invited to submit dissertations on subjects of their choice and those of sufficient merit were to be taken into account in the election.[112] Since a college fellowship was one of the few options open to Cambridge graduates who wished to pursue a career in academic mathematics, the competition for fellowships was intense, providing ample motivation for candidates to engage in the additional work.

This innovation in the fellowship appointment process had a twofold effect. Not

[110] A. Cayley, 'A Smith's Prize Dissertation', *Messenger of Mathematics*, 2 (1873), 36–7, 145–9, 161–6; 3 (1874), 1–4; 4 (1875), 157–60.

[111] Cayley's problem papers appeared in the *Quarterly Journal of Pure and Applied Mathematics*, 8, 7–10; *Oxford, Cambridge and Dublin Messenger of Mathematics*, 4, 201–26; 5, 40–64, 182–203; and *Messenger of Mathematics*, 1, 37–47, 71–7, 89–95; 3, 165–83; 4, 6–8; 6, 173–82.

[112] Trinity was the first college to introduce competitive examinations for prize fellowships. These examinations consisted of two mathematical papers, and one paper on another subject (not mathematical). Prior to 1872 the awarding of these fellowships was founded mostly on performance in the Tripos.

only were the electors provided with an additional measure by which to guide their selection, and often it was the dissertation on which the examiners placed the greatest weight,[113] but also many of the dissertations were later published providing lasting contributions to mathematical research.[114] The new idea served its purpose well and St John's and King's shortly followed Trinity's example. It was thus both a model and a stimulus for the Smith's Prize reformers.

There was therefore a growing sentiment within the university in favour of essays as a means of distinguishing students. So when the Syndicate delivered their conclusions in March 1878 it came as no surprise that they recommended that the examination should be discontinued and instead the prizes should be given 'for the best two essays on a subject or subjects in Pure Mathematics or Mathematical Physics, the Candidates being Bachelors of Arts of not more than one year's standing'.[115] Although support for the proposal was not unanimous there were only a handful of objectors. The general feeling was that the content of the two sets of examinations was now so close that the advantage once held by the Smith's Prize examination of mathematically stretching candidates had been virtually eroded. J. W. L. Glaisher, one of Trinity's most accomplished lecturers, felt so strongly in favour of the proposal that he made a special appeal to the Senate urging them to agree to it. He argued:

> ... that if the Smith's Prizes be given for essays, they will at the same time directly encourage Mathematical Science and will enable those students, who are possessed of real mathematical ability, and yet are unable to answer a number of difficult questions in the three hours of an examination paper, to receive the reward they merit. ... As it is, the quick and ready student has it all his own way in examinations; and I should like to see an opportunity given to the wise and thoughtful student of showing his capacity and knowledge.
>
> As regards the encouragement of the science of mathematics, an undergraduate obtains all his information from textbooks, lecturers, private tutors, &c., and as a rule is totally in the dark as to the present state of knowledge on the subjects of which he is learning the elements. If ... he endeavours to apply his mathematical knowledge to some scientific question, he is almost certain at first to find that he has been anticipated, and is probably disheartened on learning of the vast mass of modern mathematical literature, of the existence of which he was wholly ignorant ... the great defect of the Cambridge training, from a scientific point of view, is that the student never has to search out for himself the original memoirs in which the results of mathematical investigations are first

[113] The status of the dissertation in the fellowship election during this period is not clear. Lowe, in his discussion of Whitehead's fellowship election of 1884, described the dissertation as being that part of the examination on which Trinity placed 'the greatest weight'. See V. Lowe, *Alfred North Whitehead: The Man and His Work*, vol. 1: 1861–1910 (Baltimore, 1985), 106. But this view is contrary to that given by Stewart in his discussion of Francis Jenkinson's fellowship election in 1878 in which he says that 'The examination was everything in those days and the dissertations counted for very little.' See H. Stewart, *Francis Jenkinson, Fellow of Trinity College Cambridge and University Librarian. A Memoir* (Cambridge, 1926), 14. However, according to E. T. Whittaker by the mid-1890s the dissertation had become all-important. See R. J. Cook, 'Letters Home I. E. T. Whittaker at Trinity College in 1896', unpublished article.

[114] For example R. C. Rowe's 'Memoir on Abel's Theorem', *Philosophical Transactions of the Royal Society*, 172 (1882), 713–50, and A. R. Forsyth's 'Memoir on the Theta Functions, particularly those of two variables', *Philosophical Transactions of the Royal Society*, 173 (1883), 783–862. These were probably two of the papers that Glaisher had in mind when he remarked in 1883 that 'the essays from Trinity had certainly given three most important papers to the world'. *Cambridge University Reporter*, 14 March 1883, 509–12.

[115] Mathematics Registry File, CUR 28.6.1. *Cambridge University Reporter*, 2 April 1878, 423.

given to the world; all he learns is obtained second-hand from the text-books or teachers. But this will be partly remedied by the proposed scheme for the Smith's Prizes, for the student will have to make himself acquainted to some extent with the journal literature... the advantage of thus bringing the higher wranglers, hitherto confined to the dry bones of the subjects contained in text-books, face to face with the living works of the mathematicians of the day, would be very great. In case any one should think I am exaggerating the importance of this matter, I may point out that probably in no subject is the proportion of book literature to journal literature nearly so small as in mathematics. The science progresses fast, but the audience addressed is small; the books written are few, and the great proportion of them are only intended for purposes of elementary instruction...[116]

Glaisher's plea reveals a clear concern over the stultifying nature of the Tripos system and its potential consequences for the future of Cambridge mathematics. As the system stood there was no incentive for students to engage in research. Worse still the best students could be driven away from mathematics altogether. The new proposals provided a real opportunity for introducing a form of organized postgraduate research, something Cambridge seriously lacked.

Glaisher went on to challenge the objections that had been raised. C. H. Prior[117] had objected to the timing of the essays because he believed that the year after the Tripos was the time when students have 'least elasticity of mind for undertaking the new mathematical work which would be required for writing an essay'.[118] The highest wranglers would not compete for the prizes and the competition's prestige would be correspondingly reduced. But, Glaisher countered, if the effect of the Tripos was sufficient to prevent a wrangler from entering for the Smith's Prize, then it was an indictment on the Tripos, not on the competition. Besant, maintaining his position in support of examinations, had been concerned that the only students who would compete would be those who could afford the 'time and leisure' not having engaged in any other career. Again Glaisher found this perverse. How could time spent working on something diminish its value? Routh, one of the strongest objectors, had thought the essays would be difficult to judge and that it would be hard to distinguish original work. In response Glaisher pointed out that the Professors were both pre-eminently well qualified to judge the essays and that their assistance to the candidates would be invaluable to the university.

8. The reform is completed 1878–83

Glaisher's points were well made, the time was ripe for change and a workable alternative had been put forward. The physical endurance required to sit both sets of examinations had now reached an almost impossible level and the benefits of going through the ordeal had become increasingly marginal. In May 1878 Senate agreed that essays should replace the traditional examinations and the new scheme was scheduled for introduction in 1883. Nevertheless, the debate was not completely over. As a result of the Syndicate's proposals for the reform of the Tripos, and in particular

[116] Letter addressed to the Members of the Senate of the University of Cambridge, 28 May 1878. Mathematics Registry File, CUR 28.6.1.

[117] Charles Prior, 3rd wrangler in 1873, was a fellow and lecturer at Pembroke College.

[118] For an account of the discussion of the Mathematical Studies Syndicate Report, see the *Cambridge University Reporter*, 14 May 1878, 522–6.

their idea for a second-stage examination to be known as Part III, and to which wranglers only would be admissable, the idea of awarding the prizes by examination resurfaced. In their Report of October 1878 they included the recommendation that the prizes should be awarded in whatever manner the Senate thought fit.[119]

Thus, despite the support for essays, the possibility of using examinations for the awarding of the prizes was still kept alive. Given that the passage for change had already been well prepared with the introduction of essay-type questions into the competition and dissertations into the Fellowship elections, why the reluctance to commit to the new system?

In the first instance, there were undoubtedly some Cambridge mathematicians who would have had difficulty in accepting any change, however slight, to something they regarded as an enshrined institution. However, it is notable that two of the strongest opponents to the reform were two of the most successful of the Cambridge coaches, Besant and Routh. Was there an element of self-interest bound up in their objections? Coaching for examinations was not only their livelihood, it was their way of life. Success meant success in examinations, and their lives were so regulated that it may have been hard for them to imagine anything positive emerging from such a complete reform.[120] Furthermore, by changing the competition to essays, the coaches stood to lose, not so much in terms of clientele—students would still take the Tripos—but more in terms of status. Although success in the Senate House examination was their priority, a Smith's Prize was still an extremely desirable trophy. The coaches may also have interpreted the possible loss of the competition examination as heralding a shift away from the importance of examinations in general, in conflict with their own interests, although the introduction of Part III into the Tripos examination should have allayed their fears in that respect. In any event, it is evident that the coaches attached considerable importance to the competition.

Meanwhile, in 1879, the impending changes notwithstanding, Airy had been so dissatisfied with the year's examination that he felt it necessary to address the Senate. Apart from the proposed subjects for essays which he liked, he believed the examination to be of little use to the university.[121] Forever the supporter of applied mathematics, the main thrust of his criticism was directed towards what he saw as an excess of questions on pure mathematics. He took objection to several questions which he described as 'purely idle algebra, arbitrary combination of symbols, applicable to no further purpose' and commented that a question which came from Cayley's paper—the one enjoyed by Pearson— and contained the phrase 'where the radius is pure imaginary' was entirely beyond the range of his intellect.[122]

No official response to Airy's criticisms appears to have been recorded, although Cayley did send Airy a solution to the offending question. Airy remained unconvinced, replying, 'I am not so deeply plunged into the mists of impossibles as to appreciate fully your explanation in this instance, or to think that it is a good criterion for a University candidate'.[123] Certainly 1879 was an exceptional year from

119 Minutes of the Mathematical Studies Syndicate, CUR 28.6.1. *Cambridge University Reporter*, 29 October 1878, 97.

120 According to J. J. Thomson, the regularity of Routh's life was such that his 'occupation during term time could be expressed as a mathematical function of the time which had only one solution'. J. J. Thomson, *Recollections and Reflections* (London, 1936), 35–42.

121 Mathematics Registry File, CUR 28.6.1, and Airy (note 32), 327.

122 The complete question read 'Using the term circle as extending to the case where the radius is pure imaginary, it is required to construct the common chord of two given circles'.

123 Airy (note 32) p.327.

the point of view of the increased number of pure mathematics questions. But this can be partly explained by the fact that the question papers were set by Cayley, Maxwell, and Todhunter. Neither Maxwell nor Todhunter had set papers for the examination before and both of them set a higher proportion of pure mathematics questions than the regular examiners, Challis and Stokes.

In February 1883 the Special Board for Mathematics (SBM) prepared a report in which, amongst other things, they stated that of the three possible methods for awarding the prizes—a separate examination (the current system), an examination in Part III, or dissertations—they favoured the second option.[124] Thus they were taking a quite different position from that originally adopted by the Syndicate in 1878. However, yet again this view was by no means unanimous.[125] There were those, Cayley being one, who were against the proposal, but who did not feel sufficiently strongly against it not to sign the report. Glaisher on the other hand spoke out forcefully against it, reiterating several of the points he had made previously as well as making some new ones. He now explicitly stressed the lack of original mathematical research done by Cambridge students, especially in comparison with their foreign counterparts. He made the point that preparing a dissertation would not only give students research experience but would also provide a good opportunity for writing without the pressure of publication. As an editor of two mathematical journals, Glaisher was well qualified to make such remarks.[126]

Again Glaisher's efforts were rewarded but this time permanently. In October 1883 the SBM reissued a report—it had originally been issued in May of that year–in which it recommended 'That the prizes be awarded annually to the two candidates who shall present the essays of greatest merit on any subject in Mathematics or Natural Philosophy'.[127] They further recommended that each candidate should specify which part of their work was original, that the essays should be sent in to the Vice-Chancellor between the last day of the Michaelmas term and the first day of the Lent term next but one following their examinations in Parts I and II of the Tripos, and that the prizes would be announced on or before 1 November following. In contrast with other similar competitions, i.e. competitions requiring original research such as those emanating from national academies, there was no requirement for the candidates to send in their work anonymously. The recommended adjudicators were the Vice-Chancellor, the Lucasian, Plumian, Lowndean, Sadleirian, and Cavendish professors. It was proposed that the first award under this scheme should be made to candidates who had sat Parts I and II of the Mathematical Tripos in June 1883, and the award itself would then be made in 1885. All these recommendations were eventually agreed with the exception of the list of examiners.[128] After some discussion the name of the Cavendish professor was removed, although it was decided that he could be consulted should it prove necessary.[129] The reform was finally complete.

[124] *Cambridge University Reporter*, 27 February 1883, 423.
[125] *Cambridge University Reporter*, 14 March 1883, 509.
[126] Glaisher was editor of the *Messenger of Mathematics* from 1871 to 1928 and the *Quarterly Journal of Pure and Applied Mathematics* from 1879 to 1928.
[127] *Cambridge University Reporter*, 16 October 1883, 51.
[128] *Cambridge University Reporter*, 20 October 1883, 92.
[129] In June 1883 the Cavendish professor, Lord Rayleigh, in a letter to Members of the Senate, objected to the proposal, observing that it was 'not desirable to encourage the idea too prevalent in Cambridge that Physics is only a branch of Mathematics'. Cambridge Papers GF109.

9. Life under the new regulations

In November 1898 the SBM considered the question of whether students who had graduated from another institution and had come to Cambridge to do research (known as advanced students) should be allowed to enter the competition.[130] There were strong arguments on both sides. E. G. Gallop, who had been one of the first to win a prize under the new regulations,[131] did not think that advanced students should be allowed to compete.[132] He reasoned that an advanced student would have up to two and half years to prepare an essay in contrast with an ordinary student who, having spent four years as an undergraduate reading for his degree, would only have six months. Forsyth, the Sadleirian professor, felt quite differently. He argued strongly in favour of the Tripos as good preparation for the competition, asserting that in ten years he had not come across a single advanced student who, upon arrival at Cambridge, he considered to be properly qualified to do research. He also thought that these students would have had problems in reaching a first-class standard in Part II of the Tripos. As an example he cited a student (without disclosing a name) who had worked both at Cambridge and Berlin on a subject he himself had suggested.[133] Forsyth considered the work to be far short of the standard required for a Smith's Prize, despite the fact that the student's thesis had been accepted for a PhD in Berlin. Since earning a PhD at Berlin was a laudable and internationally recognized achievement, this was a strong claim for the quality of research generated by the competition. To substantiate it, Forsyth continued:

> On a recent occasion 7 candidates sent essays for the Smith's Prize extending to 1,000 pages of MS; four of these dissertations were published afterwards in the Transactions of learned societies, and one or two were really important contributions to mathematical learning.[134]

Although Forsyth did not name the year, it seems likely that he was referring to either 1896 or 1897, since both these years had a good number of candidates, several of whom had had their entries published.

However, despite the rationality of Forsyth's argument and the strength of his evidence, the desire of the majority of the SBM to retain the prizes exclusively for graduates of the university proved too strong, and the proposal was rejected. Since, from his experience as an examiner, Forsyth was in an ideal position to make his case, the decision suggests that the SBM may have been prompted more by concern for its own reputation than by that of its students. If advanced students entered and were more successful than their indigenous counterparts, it would reflect little credit on the standard of Cambridge teaching.

The first decade of the twentieth century saw a radical change to the Tripos system. In 1906, after a fierce, prolonged and acrimonious debate, the order of merit was finally abolished, the last rankings taking place in 1909. And although the competition was not directly affected, it was occasionally caught in the crossfire.

[130] *Cambridge University Reporter*, 17 January 1899, 438.

[131] E. G. Gallop was a fellow and lecturer at Caius, and his winning essay 'The distribution of electricity on the circular disc and spherical bowl', was published in the *Quarterly Journal of Mathematics*, 21 (1886), 229–56.

[132] *Cambridge University Reporter*, 14 March 1899, 676.

[133] For a student studying a subject suggested by Forsyth but who wished to study abroad, Berlin, as the centre for pure mathematics research in Germany, would have been a natural choice.

[134] *Cambridge University Reporter*, 14 March 1899, 676.

In May 1906 a group of nineteen non-mathematical Members of Senate sent a letter to the SBM arguing in favour of abolishing the order of merit. In it they expressed the then commonly held opinion that the Smith's Prize competition furnished a safer test of ability than the Tripos.[135] Their argument was supported by reference to the Tripos positions of recent Smith's Prize winners. These showed that winning a prize no longer necessitated a high ranking in the Tripos. However, rather than supporting their case, their letter revealed that they were ignorant of the differences that now existed between the two contests. In the first instance, the non-mathematicians had failed to take into account that the prizes were no longer automatically contested for by the highest-ranking wranglers since many of these were prevented from staying on in Cambridge after the final Tripos examination. Second, and more to the point, they did not appreciate that the results showed the distinction between the capacity for examination work and the capacity to write an original thesis. It was not, as they thought, that the Smith's Prize competition provided a better benchmark. One of those caught up in the discussion, G. T. Bennett,[136] evocatively captured the distinction between the two contests by likening it to the difference between the Derby and the Grand National.[137]

One of the strongest arguments for the abolition for the order of merit was the serious decrease in the number of students sitting the Tripos, and this was reflected in the Smith's Prize competition, or so it was claimed. In a letter to the SBM, Forsyth pointed out that in 1895 there were 101 students ranked in the Tripos and seven entrants to the competition, whereas the corresponding numbers for 1905 were fifty-seven and two.[138] However, in 1907 when there were still only sixty-four Tripos students, there were at least five entrants for the Smith's Prize competition, and in the following year the corresponding numbers were eighty-three and eight. In both these years the entrants for the Smith's Prize were graduates under the old system. Thus while there was some substance to Forsyth's claim, the competition does not appear to have suffered unduly. What might have been thought more relevant to entry for the competition was the inherent logistical and/or financial difficulties associated with staying on at Cambridge for a further year, but these too do not appear to have had an adverse effect.

Despite its rather prolonged gestation, once implemented the essay system appears to have gained rapid and wide acceptance, although it did have detractors. W. H. Young, writing in 1915, felt that:

> The results of this competition have been in my opinion on many occasions quite unsatisfactory. And it was bound to be so. The subject thought of by the candidate was not likely to be a good one if he trusted to his unaided efforts, and if he took advice of an older person the competence of this person was not likely to be always undoubted, and, even when it was, the choice of the subject might still be unsatisfactory.[139]

Since supervision was by no means compulsory, and certainly not regulated, there was undoubtedly some validity to Young's criticism. But he gave no hint as to which

[135] Minutes of the Mathematical Studies Syndicate, CUR 28.6.2. (36l).

[136] Geoffrey Bennett (1868–1942), who was senior wrangler in 1890 and 1st Smith's Prizeman in 1892, was a lecturer and senior fellow of Emmanuel.

[137] Minutes of the Mathematical Studies Syndicate, CUR 28.6 2 (36v).

[138] Ibid. (36aa).

[139] I. Grattan-Guinness, 'University mathematics at the turn of the century. Unpublished recollections of WH Young', *Annals of Science*, 28 (1972), 369–84 (374).

particular results he found unsatisfactory and it is possible that his opinions were coloured by personal experience. It is not known whether he entered the competition, but, as a graduate of 1884, had he done so it would have been under the new regulations, which he may well have found unsatisfactory. Nevertheless, despite Young's comments, the competition produced some outstanding essays from the outset and it continued to do so. Furthermore, there was expert supervision taking place as, for example, in the case of the geometer H. F. Baker who freely acknowledged Cayley's guidance with his winning entry.[140]

With the introduction of the essay-based format, the competition provided a welcome incentive for postgraduate research. Although there were fellowships to strive for, these were keenly contested and it was rare for a student to be awarded one at his first attempt. The competition was attractive not only because it opened up the possibility of achieving public recognition for research but also because it did so within a set time frame. It provided a mechanism whereby students could try their hand at research without first making a long-term academic commitment. Furthermore, for those for whom gaining a fellowship was either impossible or undesirable, the prizes provided a mechanism for undertaking research prior to seeking employment outside Cambridge. Students who tried for a prize, even if they were not successful, gained knowledge of a research environment and were better prepared to stimulate research outside the university as well as within it.

10. Smith's Prize essays 1885–1940

When the competition results for the first year under the new regulations were announced, they included not only the details of the prize-winning essays but also the details of two others considered sufficiently good to be 'worthy of an honourable mention'. From then on the idea of naming 'runners-up' became a standard practice. Appendix 1 shows that many essays were placed in this category and that the number varied from year to year.[141] On occasions the number of actual prizes was increased, as for example in 1904 when four prizes were awarded. This practice of increasing the number of awards and including additional citations provided greater opportunity for low-ranking wranglers seeking to raise their reputations. One of the most notable examples was Philip Jourdain who was unclassified in the Tripos but whose Smith's Prize essay received an honourable mention. This kind of advance in academic position confirmed the advantages of the revised system. It not only gave a chance to those for whom writing an essay was a more natural way to demonstrate their ability, but it also removed the stress attached to the sitting of examinations, and it allowed time for a full recovery from the ordeal of the Tripos. In contrast, under the old system, the practice of awarding only two prizes had been almost invariably adhered to, the only exceptions being in 1809, 1877 and 1881 when two second prizes were awarded. The new regulations, therefore, had the additional benefit of liberating the examiners from the practice of acknowledging only the winners. The increased number of awards also provided a greater incentive to enter the competition to the benefit of the general research enterprise.

[140] H. F. Baker, 'On the full system of concomitants of three ternary quadrics', *Transactions of the Cambridge Philosophical Society*, 15 (1889), 62–106 and W. L. Edge, 'H F Baker, FRS', *Edinburgh Mathematical Notes*, 41 (1956), 10–28.

[141] The results of the competition, including the titles of the winning and commended essays, are published in the *Cambridge University Reporter*.

No record appears to have been kept of the essays submitted, so it is hard to gauge the strength of competition in any one year although some scattered evidence has come to light. On 8 May 1896, Whittaker,[142] in a letter to his mother, wrote:

> It is expected that the results of the Smith's Prizes for the year above me will be out on Saturday or Monday. Adie and Leathem are I think most generally expected to get them, but Sedgwick, Philip, Lawrence, Campbell and Kelsey, are all supposed to have some chance.[143]

And again on 15 May:

> The result of the Smith's Prizes came out last Saturday: Adie who was bracketed Senior Wrangler, got the first, and Lawrence (bracketed fourth) and Campbell (bracketed eighth (*sic*)) were bracketed for the second. It is a great disappointment to Sedgwick, who was bracketed with Adie in the Tripos, and to Philip who was third in the Tripos.[144]

From this it can be deduced that there were at least seven candidates in 1896, although only three received recognition. The following year, when Whittaker himself won the first prize, six of the candidates received recognition including R. C. Maclaurin who, as 12th wrangler, was another beneficiary of the changed regulations.[145]

There is no repository for the winning essays, and neither were they ever published as such. Nevertheless, as already indicated, many of the essays did form the basis for publications. In several cases, these papers are of such high quality that they are singled out for special mention in commentaries on the authors' work, a typical example of which is G. T. Bennett's essay, which was communicated to the Royal Society by Cayley.[146] Others include the essays of H. F. Baker (1889), R. A. Sampson (1890), J. H. Jeans (1901), L. J. Mordell (1912), and W. D. V. Hodge (1927).

For the purposes of considering the subjects of the winning and commended essays, i.e. those listed in Appendix 1, it is convenient to divide the period into three: 1885–1900, 1901–20, and 1921–40. In the first interval, there is an almost equal split between pure and applied mathematics, with a fairly even distribution of subjects between algebra and arithmetic (considered together), analysis, mechanics, and mathematical physics, although there are slightly more essays in the latter two categories. The one subject which did less well than the others in this period was geometry. During the second interval, applied mathematics fared better, with applied essays outnumbering pure by a ratio of approximately 3:2. This increase is accounted for by a growth in the number of essays on topics in mathematical physics, electricity in particular, as well as the appearance of essays on topics in celestial mechanics. Essays on pure topics in this period were fairly evenly distributed among subjects, with the exception of analysis, which was in the majority. In the third interval, the

142 E. T. Whittaker, who was 2nd wrangler in 1895, became Astronomer Royal for Ireland in 1906, and was elected to the chair of mathematics at Edinburgh in 1912, a post which he held until his retirement in 1946.

143 Cook (note 113). All the names mentioned were Wranglers in 1894: Adie and Sedgwick were bracketed Senior, Philip was 3rd, Lawrence and Leathem were bracketed 4th, Campbell was bracketed 9th, and Kelsey was bracketed 11th.

144 Ibid.

145 R. C. Maclaurin (1870–1920) went on to become professor of mathematics at Victoria University College, Wellington, New Zealand, and then professor of mathematical physics at the University of Columbia, USA, before becoming President of MIT in 1909.

146 H. F. Baker, 'G R Bennett', *Journal of the London Mathematical Society*, 19 (1944), 107–28. Bennett's essay was published in the *Philosophical Transactions of the Royal Society A* (1894), 189–336.

situation was reversed with the ratio of the number of essays in pure mathematics to applied being approximately 5:4. During this period there was a substantial increase in the number of essays on both analysis and geometry, the number in each case more than doubling.

The variation in the popularity of the different subjects ties closely to the variation in the research interests of the leading Cambridge mathematicians of the time. For example, the rise in the numbers of geometry and analysis essays can reasonably be attributed to the presence of H. F. Baker (Lowndean Professor 1914–36), and G. H. Hardy (Sadleirian Professor 1931–42), respectively, both of whom made strenuous efforts to build up research schools in their particular subjects. Likewise the continuing strength of mathematical physics can be ascribed to the influence of Joseph Larmor (Lucasian Professor 1901–32), and Ralph Fowler (Plummer Professor of Mathematical Physics 1932–44). On the other hand, the relatively small but fairly constant number of essays on algebraic topics accords with the lack of a driving force in the subject.

In the period prior to the establishment of the PhD in Cambridge,[147] the results of the Smith's Prize competition provide one of the few explicit sources of information about Cambridge postgraduate research in mathematics. After the introduction of the PhD, there developed a correspondence between prize-winning essays and PhDs, with a number of essays being worked up into theses. The degree was usually awarded a year or so after the prize, although the first person to gain both a Smith's Prize and a PhD was T. M. Cherry who collected both in 1924, the first year a PhD in mathematics was awarded in Cambridge. Nevertheless, up until the end of the Second World War it was not unusual for research students to enter for the Smith's Prize but not to take a PhD, as for example in the case of Fred Hoyle. In some instances, such as that of W. V. D. Hodge, the Smith's Prize essay was completed after the graduate had left Cambridge. Hodge, having successfully completed the Tripos in the summer of 1925, immediately embarked on research under the informal supervision of Baker, but with no intention of taking a PhD degree.[148] In 1926 he took up an appointment as an assistant lecturer at Bristol and it was while he was there that he finished his essay.[149]

After the Second World War, as the PhD became more fully integrated into the Cambridge system, entering for the Smith's Prize competition became a customary part of the course towards a PhD. The discipline in preparing an essay was recognized as useful in building towards a PhD as well as providing a good incentive to prepare work for publication.

11. The Rayleigh and Knight Prizes

In 1908 Lord Rayleigh was unanimously elected as Chancellor of the University of Cambridge, and to commemorate the event a number of his scientific friends organized a collection for the founding of an award to be called the Rayleigh prize.

[147] The PhD was formally accepted in Cambridge in 1919. See R. Simpson, *How the PhD came to Britain. A Century of Struggle for Postgraduate Education* (Society for Research into Higher Education, 1983), 147.

[148] M. F. Atiyah, 'William Vallance Douglas Hodge', *Bulletin of the London Mathematical Society*, 9 (1977), 99–108 (103).

[149] In Bristol Hodge benefited from the presence of Peter Fraser (1880–1958), a Cambridge graduate, who had become reader in geometry there. Hodge was also fortunate in his head of department, Henry Hassé (1884–1955), who did everything possible to enable him to concentrate on his research, and who had himself been highly commended for a Smith's Prize in 1908.

Lord Rayleigh, himself 1st Smith's Prizeman in 1865, proposed that the fund (which totalled £812) should be used to supplement the Smith's Prizes. His idea was timely. The growing specialization in the higher branches of mathematics and the wide variety of theses submitted for the Smith's Prizes had meant that the task of the examiners had become increasingly difficult. His proposal, enthusiastically adopted, was that:

> ... at the discretion of the examiners, in good years, instead of a division of the Smith's Prizes, a third or fourth prize might be given from the Rayleigh prize fund in addition to the two Smith's Prizes, and that in weaker years the prizes might be limited to the first and second Smith's Prizes.[150]

The first Rayleigh prize was awarded in 1911, two years after the abolition of merit in the Tripos. These new prizes worked well because they allowed the examiners both to reward a broader cross-section of subjects and to be more flexible in the number of prizes they awarded.

In 1973 the Smith's Prizes were further supplemented by the addition of the Knight prize. This prize is open to second-year research students who have graduated outside Cambridge and are therefore ineligible for either the Smith's or Rayleigh prizes. It was founded in memory of J. T. Knight, a research fellow who graduated from Glasgow University, received his doctorate from Cambridge in 1967, and died in a road accident in 1970.

12. Prizemen and wranglers

Before the regulations changed in 1883, there was a high correlation between the winners of the Smith's Prizes and the senior wrangler (see Appendix 2). From 1769 to 1883 inclusive, the senior wrangler won the first Smith's Prize on ninety-six occasions and the second Smith's Prize on eleven occasions. Thus during the 115-year period there were only eight years when the senior wrangler failed to win either of the prizes. The 2nd wrangler also fared well during the period. Eighteen 2nd wranglers won 1st Smith's Prizes, while 75 won 2nd Prizes. There were only two years in which neither a senior nor a 2nd wrangler was awarded a prize, and the first of these did not occur until 1859.[151] Thus for the first 116 years of the competition the Smith's Prizes winners and the leading wranglers were virtually synonymous, although it was not until the competition was in its fifth year that two results exactly mirrored one another.

Although the competition took a few years to get established into a pattern whereby the two leading wranglers almost invariably shared the honours, the trend was basically set from the outset. In 1769 the Prizes went to the 3rd and senior wrangler respectively. The 1st Prizeman, George Atwood, was one of the most distinguished mathematicians to emerge from Cambridge in the eighteenth century. He was elected to the Royal Society in 1776, and was the author of an extensive treatise on mechanics.[152] The 2nd Prizeman was Thomas Parkinson. He was elected

[150] *Cambridge University Reporter*, 8 December 1908, 298.

[151] No allowance has been made for those wranglers who, despite having succeeded in the Tripos, were not graduates of the university and so were unable to compete for a prize. For example, both A. De Morgan, 4th wrangler in 1827, and J. J. Sylvester, 2nd wrangler in 1837, were unable to graduate with their class owing to their religious convictions and would surely have been strong contenders had they been allowed to enter.

[152] G. Atwood, *A Treatise on the Rectilinear Motion and Rotation of Bodies*: *with a Description of Original Experiments Relative to the Subject* (Cambridge, 1784).

to the Royal Society in 1786, and he also published on mechanics.[153] It is perhaps no coincidence that the first beneficiaries of Smith's bequest developed mathematical interests compatible with those of their benefactor.

The close correlation between the results in the two contests during this first period confirms the high level of academic prestige attached to victory in the competition. The leading wranglers already had their reputations made, and the financial reward attached to the competition, while attractive, cannot account for why so many were tempted into a second gruelling set of examinations. Since the differences between the contests meant that success in one did not automatically translate into success in the other and achieving success required considerable effort, it appears that the motivation for entering derived largely from a desire to win academic approbation beyond that bestowed through the Tripos.

The situation was noticeably different under the new regulations. Of the wranglers who graduated between 1883 and 1909 (the last year in which wranglers were ranked) only eighteen out of thirty-five seniors[154] won either a Smith's Prize or a Rayleigh Prize, while of the 2nd wranglers, eighteen out of twenty-seven won a prize. Furthermore, under the old regulations, although it was possible for those who had done disappointingly in the Tripos to redeem themselves in the Smith's Prize examination, it was extremely rare for anyone to recover more than one or two positions. However, between 1885 and 1912, there are several examples of lower ranking wranglers winning a prize (see Appendix 1). This change in profile is not unexpected given both the change in skills required and the fact that entering the competition now involved making at least a short-term career commitment to mathematics. In general, candidates spent a year preparing their essays, having spent the previous three or four years working for the Tripos.[155] Under the old regulations candidates could relinquish their commitment to mathematics within weeks of the end of the Tripos examinations.

13. Conclusion

In studying the history of the Smith's Prizes, a clear division into two phases has emerged. In the first, from 1769 to 1883, the competition consisted of a set of examinations that ran parallel with the Mathematical Tripos examinations. Although the two contests appeared quite similar, they have been shown to be quite different. Two particular features of the competition stand out: the explicit support for natural philosophy and the involvement of the professoriate. In this first phase, these two factors more than any others helped to shape the competition, contributing largely to its success and its ultimate effect on the study of mathematics at Cambridge.

During the early years of the competition, several of the examiners had been

[153] T. Parkinson, *A System of Mechanics*: *being the Substance of Lectures upon that Branch of Natural Philosophy* (Cambridge, 1785), and *A System of Mechanics and Hydrostatics, being a Substance of Lectures upon those Branches of Natural Philosophy* (Cambridge, 1789).

[154] The higher than expected number of senior wranglers within the time span is due to the years when two or more students were bracketed together.

[155] Between 1882 and 1886 the Tripos was divided into two sections: Parts I and II (together) held in June and classified according to merit; and Part III (to which only wranglers were admissible) taken the following January and classified in three divisions with the names being given alphabetically within each division. From 1886 to 1909 Part I was classified according to merit, while Part II, to which only wranglers were admissible and which was taken a year later, was classified in three classes with three divisions in each class. From 1910 the examination was again divided into two parts. Each part was arranged in three classes, with Part II open to all Part I candidates, and the wranglers, arranged alphabetically, making up the top class of Part II.

acquainted with Smith personally.[156] Personal knowledge combined with the specific mention of natural philosophy in the bequest would have encouraged them to be diligent with regard to its inclusion in the examinations and the records indicate that this was indeed the case. In the nineteenth century, the situation changed. As a result of his publications Smith's academic standing remained high but the personal connections had gone and in their place stood Airy, one of the most redoubtable figures of Victorian science. Airy, an unequivocal supporter of applied mathematics, maintained an active interest in the competition throughout his working life, despite the majority of it being spent outside Cambridge. From his position at Greenwich he was well placed to voice concern about the insular nature of the teaching at the university. It was a characteristic he deplored and one that he believed the competition, properly run, could help counteract. His continual exhortations to sustain, or even increase, the amount of applied mathematics within the competition were effective, and his contributions were especially pertinent in the years following Arthur Cayley's appointment as an examiner. Cayley, the first pure mathematician in the nineteenth century to make a significant contribution as an examiner, found his questions under fire and Airy's vigorous attacks kept the issue of content under continuing debate. Airy's involvement was a key factor in ensuring the origins of the competition and the spirit of its benefactor were not forgotten.

The work of the professors in connection with the examination was beneficial at several levels. In the first instance, it provided a direct channel of communication between them and the undergraduates, a channel that was otherwise often missing. Second, having to set examination questions meant that the professors had to know what was being examined in the Tripos. This meant that they were kept in touch with the university's teaching, whether or not they were participating in it in some other way. The additional knowledge they gained through their involvement in the competition was particularly useful in debates on teaching, particularly those to do with issues concerning Tripos reform. Furthermore, their practice of posing questions in which candidates were expected to show insight or originality helped to promote a climate supportive of creative thought.

Considered from a broader perspective, the continued involvement of the professoriate in an event supporting the study of natural philosophy, or applied mathematics, was helpful in sustaining an environment receptive to such areas of research. The existence of the examination required examiners to maintain an interest in applied subjects while simultaneously engendering confidence in the same subjects in successful students. From the competition's outset, many of these students went on to become extremely accomplished applied mathematicians with several eventually becoming examiners themselves. The competition can thus be seen as one of the bridges connecting the Newtonianism advocated by Cotes and Smith to the splendid successes in mathematical physics more than a hundred years later. The continuity in applied mathematics teaching inherent in the competition provides one of the reasons why Cambridge applied mathematics research in the nineteenth century was so much stronger than its pure counterpart.

During the second phase of the competition's history, from 1885 onwards, when there were no longer examinations but candidates were required to submit essays, the competition actively stimulated mathematical research. The transition to essays was

[156] For example, both Edward Waring, the Lucasian professor, and Anthony Shepherd, the Plumian professor, who were in office when Smith died in 1768, retained their chairs until 1798 and 1796 respectively.

a slow process but once complete it opened up the possibility of properly organized postgraduate research. Until then Cambridge's postgraduate research had lagged far behind that of its Continental rivals, e.g. Berlin and Paris, which had had strong well-established postgraduate research traditions for many years. Cambridge at last could begin to compete. Several of the professors, although under no statutory obligation to do so, supervised essays and with their support many distinguished research careers were launched. By the end of the nineteenth century more than favourable comparisons were being drawn between prize-winning essays and Continental theses. The PhD did not arrive in Britain until the end of the second decade of the twentieth century, but when it did the Cambridge mathematicians were prepared. The Smith's Prize institution had equipped them for the challenge. They were ready to take it up and treat it on their own terms.

Robert Smith, mathematician and educational benefactor, may not be numbered among the most famous of Cambridge's mathematicians, but the enduring success of his bequest has ensured that his name will be remembered.

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Appendix 1. List of Prize Winners and their Essays 1885–1940

Tripos positions are indicated by numbers in square brackets.
S1—1st Smith's Prize; S2—2nd Smith's Prize; S—Smith's Prize; h—deserving honourable mention; m—essay of great merit; d—essay of distinction; R—Rayleigh prize.

Year	Award	Name	Title of Essay
1885	S	E. G. Gallop [2]	The distribution of electricity on the circular disc and spherical bowl
	S	R. Lachlan [3]	On systems of circles
	h	C. Chree [6]	On elastic solids
	h	A. N. Whitehead [3]	The general equations of hydrodynamics
1886	S1	W. P. Workman [2]	The theory of singular solutions of integrable differential equations of the first order; with extensions to the independent variables
	S2	R. F. Muirhead [17]	The laws of motion
1887	S1	A. E. H. Love [2]	The small free vibrations of a thin elastic shell, and on the free and fixed vibrations of an elastic spherical shell containing a given mass of liquid
	S2	A. Berry [1]	Joint reciprocants
1888	S	G. H. Bryan [5]	The waves on a rotating liquid spheroid of finite ellipticity
	S	A. C. Dixon [1]	The doubly periodic functions arising out of the curve $x^3 + y^3 - 3axy = 1$
1889	S	H. F. Baker [1]	The complete system of 148 concomitants of three ternary quadrics in terms of which all others are expressible as rational integral algebraic functions, with an account of the present theory of three such forms
	S	J. H. Michell [1]	The vibrations of curved rods and shells

Appendix 1 (cont.)

Year	Award	Name	Title of Essay
1890	S1	R. A. Sampson [3]	Stokes' current function
	S2	W. E. Brunyate [2]	The associated concomitants of ternary forms
	m	J. Buchanan	(No title given)
1891	S	F. W. Dyson [2]	The potential of ellipsoids of variable densities and also of the anchor ring in external space
	S	H. M. Macdonald [4]	The self-induction of two parallel currents
	m	G. T. Walker [1]	(No title given)
1892	S1	G. T. Bennett [1]	The residues of powers of numbers for any composite real modulus
	S2	H. W. Segar [2]	Determinantal theorems
	h	L. Crawford [5]	Ellipsoidal harmonics and Lamé's equation
1893	S	C. E. Cullis [7]	The motion of perforated solids in incompressible liquid
	S	D. B. Mair [2]	The continuous deformation of surfaces
	S	R. H. D. Mayall [2]	Certain forms of current sheets
1894	S	S. S. Hough [3]	The oscillations of an ellipsoidal shell containing fluid
	S	H. C. Pocklington [4]	The steady motion and small oscillations of an electrified hollow vortex
1895	S1	G. T. Manley [1]	The conformal representation of a quadrilateral on a half plane
	S2	G. H. J. Hurst [2]	Electromagnetism and magneto-optic rotation
	h	H. E. Atkins [9]	An exposition of Kummer's proof of Fermat's last theorem
	h	P. E. Bateman [1]	The electromagnetic field set up by charged bodies in steady motion
1896	S1	W. S. Adie [1]	Discontinuous fluid motion in two dimensions
	S2=	A. Y. G. Campbell [9]	The differential equations of theoretical dynamics
	S2=	F. W. Lawrence [4]	Methods of factorisation
1897	S1	E. T. Whittaker [2]	On the reduction of the theory of multiform functions to the theory of uniform functions
	S2=	R. C. Maclaurin [12]	On the solutions of the equations $(\nabla^2 + \kappa^2)\,\Psi = 0$ in elliptic coordinates, and their physical applications
	S2=	A. E. Western [7]	On certain systems of quadratic complex numbers
	h	T. J. I.'A. Bromwich [1]	On various problems of elasticity suggested by earthquake phenomena
	h	B. Hopkinson [aeg]	An extension of Schwarz's transformation with applications
	m	C. Godfrey [4]	Fluorescence
1898	S1	E. W. Barnes [2]	On extended gamma-functions and Bernoullian numbers
	S2	B. A. Houston [5]	On some steady motions of electrons connected with the internal molecular constitution of matter
1899	S	W. H. Austin [1]	The motion of a symmetrical top on a smooth horizontal plane
	S	G. W. Walker [4]	On the scattering of light by small slightly conducting particles
	h	F. W. B. Frankland [3]	The theory of parallelism
	h	F. J. W. Whipple [2]	On the stability of the motion of a bicycle
1900	S	J. F. Cameron [2]	On molecules considered as electric oscillators
	S	R. W. H. T. Hudson [1]	Ordinary differential equations of the second order and their singular solutions

Appendix 1 (cont.)

Year	Award	Name	Title of Essay
1901	S	G. H. Hardy [4]	Definite integrals of discontinuous functions
	S	J. H. Jeans [4]	The distribution of molecular energy
	h	P. V. Bevan [4]	The influence of metallic media on light vibrations
1902	S	T. H. Havelock [15]	On the distribution of energy in the continuous spectrum
	S	J. E. Wright [1]	Singular solutions of differential equations with known infinitesimal transformations
	h	H. E. Wimperis	The temperature of meteorites
1903	S	H. Knapman [2]	On the theory of optical phenomena in a dielectric
	S	A. P. Thompson [5]	On the order of the irreducible covariant system of any number of binary forms of given orders
	h	W. H. Jackson [3]	On the diffraction of light produced by a metallic wedge of finite angle
1904	S	E. Cunningham [1]	On the normal series satisfying linear differential equations
	S	J. C. M. Garnett [16]	On the cause of colour in metal glasses and metallic films
	S	H. A. Webb [3]	On the expansion of an arbitrary function in a series of functions
	S	P. W. Wood [3]	On covariant types
	h	P. E. B. Jourdain	On the transfinite cardinal numbers of well ordered aggregates
1905	S	H. Bateman [1]	The solution of linear differential equations by means of definite integrals
	S	P. E. Marrack [1]	Absorption by matter of Röntgen and 'γ' rays
1906	S	C. F. Russell [14]	On the geometrical interpretation of apolar binary forms
	S	F. J. M. Stratton [3]	On a problem in tidal evolution suggested by the motion of Saturn's 9th satellite
1907	S	G. R. Blanco-White [2]	Fluorescence
	S	A. S. Eddington [1]	The systematic motion of the stars
	S	J. W. Nicholson [10]	The bending of waves around a large opaque sphere and some associated problems
	S	W. M. Page [8]	The variation of the absorption bands in the spectrum of a crystal under the action of a magnetic field
	h	H. J. Priestley [5]	Some problems on the diffraction of electric waves
1908	S	W. J. Harrison [3]	Problems in the wave-motion of viscous liquids
	S	J. E. Littlewood [1]	On the asymptotic behaviour of integral functions of zero order, and allied problems
	S	J. Mercer [1]	On the solution of ordinary linear differential equations having doubly periodic coefficients
	h	C. W. Follett [10]	On energy accelerations and partition of energy
	h	H. R. Hassé [7]	On some problems in the theory of metallic reflection
	h	W. P. Milne [4]	The geometry of apolar triads
	h	H. T. H. Piaggio [10]	Perpetuant syzygies of the nth kind
	h	C. J. T. Sewell [1]	The reflection of plane waves of light at the surface of a medium of special periodic characters
1909	S	H. Turnbull [2]	The irreducible concomitants of 2 quadratics in n variables

Appendix 1 (cont.)

Year	Award	Name	Title of Essay
	S	G. N. Watson [1]	The solution of the homogeneous linear difference equation of second order, and its application to theory of linear differential equations of Fuchsian type
1910	S	G. I. Taylor [22]	Discontinuous motion in gases
1911	S1	G. H. Livens [4]	The influence of density on the position of the emission and absorption lines in a gas spectrum
	S2	W. E. H. Berwick [4]	An illustration of the theory of relative corpora
	R	S. Lees [24]	The scattering of a stream of very small particles by matter
	m	C. G. Darwin [4]	On a theory of the cause of magnetic storms
	m	A. W. H. Thompson [4]	A research in projective geometry
1912	S1	E. H. Neville [2]	Moving axes; curvilinear co-ordinates; differential geometry
	S2	L. J. Mordell [3]	The Diophantine equation $y^2 = x^3 + k$
	R	P. J. Daniell [1]	Diffraction of light for the case of a hole in a plane of perfectly reflecting screen
1913	S1	S. Chapman	1. On the kinetic theory of a gas constituted of spherically symmetric molecules. 2. Various papers on the theory of infinite series of integration
	S2	H. S. Jones	The scattering of plane waves of light by charged spheres, with investigation of the motion produced in the spheres
	R	R. H. Fowler	A treatment of Bessel's functions by means of certain integrals involving P-functions of the variable of integration
	R	R. O. Street	The structure of the atom in relation to its spectrum
	R	T. C. Wren	A point for point representation on a plane of the quartic surface having a double straight line: and some general theorems on the surface of order N having a $(N-2)$ple straight line
	d	A. H. S. Gillson	Tidal problems
	d	A. B. Grieve	Some points in the geometry of cubic surfaces
1914	S1	J. Jackson	Retrograde satellite orbits
	S2	B. M. Sen	The geometry of unifacial surfaces
	R	R. A. Frazer	On the theory of point involution: and another paper
	d	C. A. Stewart	Partial differential equations
1915	S	H. Jeffreys	(i) Certain hypotheses as to the internal structure of the earth and moon. (ii) On a possible distribution of meteors
	S	J. Proudman	Papers on tidal motions
	R	H. Glauert	The ellipsoidal form of a rotating fluid mass as disturbed by a satellite
1916	S	H. M. Garner	Two papers on orbital oscillations about the equilateral triangle configuration in the problem of three bodies
	S	G. P. Thomson	Four papers on aeroplane problems
	R	W. M. Smart	The liberation of the Trojan planets
	d	H. M. Unthank	The determination of mean parallax of stars for different magnitudes
1917		No candidate	

Appendix 1 (cont.)

Year	Award	Name	Title of Essay
1918	S	E. L. Ince	On the continued fractions associated with the hypergeometric series; and other essays
	S	K. A. Rau	On some properties of Dirichlet's series
1919	S	C. N. H. Lock	External ballistics
	S	S. R. V. Savoor	Stability of a rotating liquid mass
1920	S	S. Pollard	The Stieltjes integral and its generalisations
1921	S1	L. A. Pars	On the general theory of relativity
	S2	W. M. H. Greaves	Periodic orbits in the problem of three bodies
1922	S	E. A. Milne	Studies in the theory of radiative equilibrium
	S	G. C. Steward	The aberration–diffraction problem
	R	T. A. Brown	On a class of factorial series
1923	S	J. C. Burkhill	Functions of intervals of the problem of area
	S	A. E. Ingham	Some value theorems in the theory of the Riemann ξ function
	R	E. F. Collingwood	The formal factorisation of an integral function of finite integral order
	R	W. R. Dean	The elastic stability of a plane plate
	R	E. C. Francis	The Denjoy–Stieltjes integral
	R	C. G. F. James	The analytical representation of systems of plane curves
	R	M. H. A. Newman	On discontinuous functions of a single real variable
1924	S	T. M. Cherry	On the differential equations of dynamics
	S	W. J. Webber	Some applications of the theory of integration
	R	E. D. Van Rest	Interferences of light
1925	S	T. G. Room	Varieties generated by collinear stars in higher spaces
1926	S	G. S. Mahajani	A contribution to the theory of ferromagnetic crystals
	S	Ll. H. Thomas	Contributions to the theory of the motion of electrified particles through matter. Kronecker's theorem in relation to adiabatic invariants
	R	T. Cooper	Some inequalities applicable to the theory of functions
	R	H. Horrocks	The effect of wind on tides and currents and the decay of waves in circular basin
1927	S	S. Goldstein	On Mathieu functions
	S	W. V. D. Hodge	Linear systems of plane algebraic curves of any genus
	R	D. Burnett	Electric radiation over the earth's surface
	R	C. A. Meredith	Some theorems on infinite cardinals
1928	S	W. L. Edge	Ruled surfaces of the 4th, 5th and 6th orders
	S	A. H. Wilson	The two centre problem in wave mechanics
	R	J. A. Gaunt	The foundation of the Debye–Hückel ionization theory with application to gases
	R	W. H. McCrea	The quantum theorem and the specific heats of gases
	d	H. P. Mulholland	Theorems on power series and Dirichlet series
	d	L. Roth	On discriminant varieties
1929	S	H. D. Ursell	On infinite periodic functions: on continued fractions: on statistical thermodynamics: on geometry
	S	J. M. Whittaker	On the theory of interpolation: on tensor theory

Appendix 1 (cont.)

Year	Award	Name	Title of Essay
	R	J. Hargreaves	Structure of spectra
	R	J. G. Semple	On quadratic and cubic Cremona transformations in 4 dimensions
	R	S. Verblunksy	The summation of trigonometrical integrals
	d	A. T. Starr	Conformal transformations with physical applications
1930	S	R. E. A. C. Paley	On Weierstrassian non-differentiable functions: and other papers
	S	J. A. Todd	Grassmannian varieties
	R	W. R. Andress	General solutions on Einsten's gravitational equations
	R	R. L. C. Young	Integrals in higher space
	d	Rv de R. Woolley	Theoretical contours of absorption lines
1931	S	H. S. M. Coxeter	Uniform polytopes
	S	H. R. Hulme	The photoelectric effect of gamma rays
	R	H. Davenport	Various topics in the theory of numbers
	R	B. Kuttner	On Fourier divisions
	R	M. J. C. Miller	Regular and Archimedean polyhedra. Stellar pulsation
	d	J. W. Archbold	On involutions and on curves of ordinary space
	d	A. J. Macintyre	Some properties of integral and meromorphic functions of finite order
1932	S	D. W. Babbage	Cremona transformations
	S	H. M. Taylor	The anomalous scattering of X-rays
	R	J. Cossar	On Fourier integrals
	R	R. W. Narliker	Cosmogeny: and astronomical dynamics
	d	J. Bronowski	On a representation of primals
1933	S	E. A. Maxwell	The invariants of certain surfaces
	S	R. H. Stoy	The planetary nebulae
	R	W. E. Candler	The stability of the rings of Saturn
	R	C. Strachan	Reflection by monomolecular flows
	R	M. H. H. Walters	The effects of stellar encounters on the orbits of binary stars
1934	S	K. Mitchell	The theory of the photoelectric effect at metal surfaces
	S	A. J. Ward	Some generalisations of the derivative
	R	M. S. Bartlett	Some series of the moment generating function in statistics
	R	C. G. Pendse	Theory of Saturn's rings
	d	J. A. Edgar	Applications of hydrodynamics on the theory of astrophysics
	d	J. M. Hyslop	Summation of divergent series
	d	G. W. Morgan	The density directions of irregular linearly measurable plane sets
	d	R. A. Smith	Collision phenomena of positive ions
1935	S	H. G. Booker	Propagation of wireless waves in the ionosphere
	S	L. Howarth	The lift coefficient for a thin elliptic cylinder
	R	A. F. Devonshire	Solution of a certain partial differential equation and its application to quantum mechanics
	R	T. E. Faulkner	Algebraic systems of curves on a surface
	R	F. Smithies	The theory of linear integral equations
	d	R. Frith	Relations between the invariants of two surfaces in (l, n) cyclic correspondence
	d	R. A. Lyttleton	The stellar case of the problem of three bodies

Appendix 1 (cont.)

Year	Award	Name	Title of Essay
	d	D. Pedoe	Problems in the theory of algebraic surfaces
	d	M. H. L. Pryce	Electrostatics in Born's theory of the electromagnetic field
1936	S	A. E. Green	Gliding problems in seaplane theory
	S	A. M. Turing	The Gaussian error function
	R	S. W. Shiveshwarkar	The dynamics of a steady stellar system with application of the rotation theory of the galaxy
	R	E. T. Goodwin	The activation of adsorbed atoms by metallic electrons
	R	D. M. A. Leggett	Two problems in elastic stability
	d	R. L. Goodstein	Theory of *R*-functions
	d	J. W. Head	The Veronesean of quadrics and associated loci
	d	M. V. Wilkes	The reflection of very long wireless waves from the ionosphere
1937	S	E. R. Love	Riemann–Stieltjes integrals
	S	H. R. Pitt	Tauberian theorems
	R	H. M. Cundy	Motion in a tetrahedral field
1938	S	F. Hoyle	Beta-disintegration
	R	G. L. Clark	The relativity theory of gravitation
	r	G. S. Rushbrooke	Strictly regular solutions
	d	A. L. Yoxall	Systems of equivalence and their applications to the geometry of algebraic varieties
1939	S1	T. A. Easterfield	A classification of groups of order p^6
	S2	H. N. V. Temperley	Co-operative phenomena
	R	J. Corner	Some applications of a recent theory of liquids
	R	D. S. Evans	The Stark effect of hydrogen in stars
	R	R. A. Rankin	Some problems of the theory of numbers
	R	D. B. Schultz	Point-curve correspondences between surfaces
1940	S	I. J. Good	The fractional dimension theory of continued fractions
	S	R. E. Macpherson	Canonical systems of equivalence on singular varieties

Appendix 2. List of Prize Winners 1769–1883

Tripos positions are indicated by numbers in square brackets.

Year	1st Smith's Prize	2nd Smith's Prize
1769	G. Atwood [3]	T. Parkinson [1]
1770	W. Smith [2]	J. Oldershaw [6]
1771	T. Starkie [1]	R. Keddington [5]
1772	G. Pretyman [1]	J. Lane [6]
1773	J. J. Brundish [1]	G. Whitmore [2]
1774	I. Milner [1]	H. Waring [3]
1775	S. Vince [1]	H. W. Coulthurst [2]
1776	J. Oldershaw [1]	W. Wright [10]
1777	D. Owen [1]	J. Baynes [3]
1776	W. Farish [1]	W. Taylor [2]
1779	T. Jones [1]	H. Marsh [2]
1780	St J. Prest [1]	W. Frend [2]
1781	T. Catton [4]	H. Ainslie [1]
1782	J. Wood [1]	J. Hailstone [2]
1783	F. J. H. Wollaston [1]	J. Procter [3]
1784	R. A. Ingram [1]	J. Holden [2]

Appendix 2 (cont.)

Year	1st Smith's Prize	2nd Smith's Prize
1785	W. Lax [1]	J. Dudley [2]
1786	J. Bell [1]	G. Hutchinson [3]
1787	J. Littledale [1]	A. Frampton [2]
1788	J. Brinkley [1]	E. Outram [2]
1789	W. Millers [1]	J. Bewsher [2]
1790	B. Bridge [1]	F. Wrangham [3]
1791	D. M. Peacock [1]	W. Gooch [2]
1792	J. Palmer [1]	G. F. Tavel [2]
1793	T. Harrison [1]	T. Strickland [2]
1794	G. Butler [1]	J. S. Copley [2]
1795	R. Woodhouse [1]	W. Atthill [2]
1796	J. Kempthorne [1]	W. Dealtry [2]
1797	J. Hudson [1]	J. Lowthian [2]
1798	T. Sowerby [1]	R. Martin [2]
1799	W. F. Boteler [1]	J. Brown [2]
1800	J. Inman [1]	G. D'Oyley [2]
1801	H. Martyn [1]	W. Woodall [2]
1802	T. P. White [1]	J. Grisdale [2]
1803	T. Starkie [1]	J. Hoare [2]
1804	W. A. Garratt [2]	J. Kaye [1]
1805	S. H. Christie [2], T. Turton [1]	—
1806	J. F. Pollock [1]	H. Walter [2]
1807	H. Gipps [1]	J. Carr [2]
1808	H. Bickersteth [1]	M. Bland [2]
1809	E. H. Alderson [1]	G. C. Gorham [3], J. Standly [2]
1810	W. H. Maule [1]	T. S. Brandreth [2]
1811	T. E. Dicey [1]	W. French [2]
1812	C. Neale [1]	J. W. Jordan [2]
1813	J. F. W. Herschel [1]	G. Peacock [2]
1814	R. Gwatkin [1]	H. Wilkinson [2]
1815	C. G. F. Leicester [1]	F. Calvert [2]
1816	E. Jacob [1]	W. Whewell [2]
1817	J. T. Austen [1]	T. Chevallier [2]
1818	J. G. S. Lefevre [1]	J. Hind [2]
1819	J. King [1]	G. M. Cooper [2]
1820	H. Coddington [1]	C. S. Bird [3]
1821	H. Melvill [2]	S. Atkinson [1]
1822	H. Holditch [1]	M. Peacock [2]
1823	G. B. Airy [1]	C. Jeffreys [2]
1824	J. Cowling [1]	J. Bowstead [2]
1825	J. Challis [1]	W. Williamson [2]
1826	W. Law [1]	W. H. Hanson [4]
1827	T. Turner [2]	H. P. Gordon [1]
1828	C. Perry [1]	J. Bailey [2]
1829	W. Cavendish [2]	H. Philpott [1]
1830	E. Steventon [3]	J. W. L. Heaviside [2]
1831	S. Earnshaw [1]	T. Gaskin [2]
1832	D. D. Heath [1]	S. Laing [2]
1833	A. Ellice [1]	J. Bowstead [2]
1834	P. Kelland [1]	T. R. Birks [2]
1835	H. Cotterill [1]	H. Goulburn [2]
1836	A. Smith [1]	J. W. Colenso [2]
1837	W. N. Griffin [1]	E. Brumell [3]
1838	T. J. Main [1]	J. G. Mould [2]
1839	P. Frost [2]	B. M. Cowie [1]

Appendix 2 (cont.)

Year	1st Smith's Prize	2nd Smith's Prize
1840	R. L. Ellis [1]	H. Goodwin [2]
1841	G. G. Stokes [1]	H. C. Jones [2]
1842	A. Cayley [1]	C. T. Simpson [2]
1843	J. C. Adams [1]	B. Gray [3]
1844	G. W. Hemming [1]	W. B. Hopkins [2]
1845	W. Thomson [2]	S. Parkinson [1]
1846	L. Hensley [1]	A. Sandeman [3 =]
1847	W. P. Wilson [1]	R. Walker [2]
1848	I. Todhunter [1]	A. Barry [4]
1849	H. C. Phear [2]	M. B. Pell [1]
1850	W. H. Besant [1]	H. W. Watson [2]
1851	N. M. Ferrers [1]	G. V. Yool [3]
1852	P. G. Tait [1]	W. J. Steele [2]
1853	T. B. Sprague [1]	R. B. Barry [2]
1854	J. C. Maxwell [2], E. J. Routh [1]	—
1855	L. H. Courtney [2], J. Savage [1]	—
1856	A. V. Hadley [1]	J. Rigby [2]
1857	T. Savage [2]	G. B. Finch [1]
1858	G. M. Slesser [1]	C. A. Smith [2]
1859	W. Jack [4]	R. B. Clifton [6]
1860	J. Stirling [1]	W. Baily [2]
1861	W. S. Aldis [1]	J. Bond [2]
1862	T. Barker [1]	J. G. Laing [2]
1863	E. T. Leeke [2], R. Romer [1]	—
1864	H. J. Purkiss [1]	W. P. Turnbull [2]
1865	J. W. L. Strutt [1]	H. M. Taylor [3]
1866	R. Morton [1]	T. S. Aldis [2]
1867	R. K. Miller [aegr]	W. K. Clifford [2]
1868	J. F. Moulton [1]	G. H. Darwin [2]
1869	J. Elliott [2]	N. E. Hartog [1]
1870	A. G. Greenhill [2], R. Pendlebury [1]	—
1871	J. Hopkinson [1], E. M. Temperley [5 =]	—
1872	R. R. Webb [1]	H. Lamb [2]
1873	T. O. Harding [1]	E. J. Nanson [2]
1874	W. W. R. Ball [2]	G. H. Stuart [5 =]
1875	W. Burnside [2]	G. Chrystal [3]
1876	J. T. Ward [1]	W. L. Mollison [2]
1877	D. McAlister [1]	R. C. Rowe [3], Smith [4]
1878	J. E. A. Steggall [2]	C. Graham [3]
1879	M. J. M. Hill [4 =], A. J. Wallis [4 =]	—
1880	J. J. Larmor [1]	J. J. Thomson [2]
1881	A. R. Forsyth [1]	R. S. Heath [2], A. E. Steinthal [3]
1882	R. A. Herman [1]	J. S. Yeo [2]
1883	W. Welsh [1]	H. H. Turner [2]