The Development of a Publication Community:
Nineteenth-Century Mathematics in British Scientific Journals

Sloan Evans Despeaux
Florence, South Carolina

B.A., Francis Marion University, 1995
M.S., Florida State University, 1997

A Dissertation presented to the Graduate Faculty
of the University of Virginia in the Candidacy for the Degree of
Doctor of Philosophy

Department of Mathematics

University of Virginia

August, 2002

Karen V. H. Parshall

[illegible]

Lawrence E. Thomas

[illegible]

Abstract

The Development of a Publication Community: Nineteenth-Century Mathematics in British Scientific Journals

This study traces the development of mathematics in nineteenth-century Britain through the analytic tool of a publication community. Specifically, we consider the nineteenth-century British mathematical publication community to consist of those who authored or read and responded in print to mathematical papers published in nineteenth-century British scientific journals. We examine this community through three different but complementary points of view: the journals, the people, and the mathematical contributions themselves.

At the level of the journals, we trace the development and structure of British scientific society-supported, independent, and university-centered journals that contained mathematical work. At the next level, we investigate the extent of professionalization and stratification in this publication community through the use of prosopography. We further trace the extent of internationalization in the community by examining the factors behind international participation in British journals and British participation in foreign journals. Finally, focusing on the journal articles themselves, we trace the intellectual contours of the community. In tracking the mathematical developments in their initial form of presentation, we highlight memorable, forgettable, and forgotten contributions, reveal topics that contemporary mathematicians viewed as popular or important, explore the theorems and theories produced by British mathematicians, and indicate trends of mathematical research in nineteenth-century Britain.

Contents

Chapter

Chapter

Chapter

ACKNOWLEDGMENTS

First of all, I thank God, without Whom this work would not have been possible.

Next, I thank my patient and incredibly supportive husband, Michael. Thank you for (repeatedly) telling me that bears prevail. Many thanks also go to my similarly patient and supportive family. Mama, Daddy, Slade, Jack, Frank, Jack, Mike, Mary Sue, David, Jeannine, Jonathan, and all manner of wonderful people from the Evans, Loy, Despeaux, and Bringhurst families.

This dissertation could not even have been attempted without the tireless support of the legions of librarians who rose to the challenge of obtaining hundreds of sources for me. They include Christine Wiedman, Lew Purifoy, Janet Key, Peggy Holley, Doug Hurd, Jimmy Breeden, and Raymond O'Donohue.

Thanks go to the Graduate School of Arts and Sciences at UVa for awarding me a Dissertation Year Fellowship. The professors, staff, and students of the UVa Department of Mathematics have also been an undying source of support. Special thanks go to my committee members, Lawrence Thomas, Harold N. Ward, and Joseph Kett as well to the LaTeX guru, Julie Riddleberger. From FSU and FMU, my thanks go out to Bettye Anne Case and Bucky Allen.

From the history of mathematics community, I especially thank Laura Martini, Adrian Rice, Deborah Kent, Della Fenster, Patti Hunter, June Barrow-Green, Ivor Grattan-Guinness, and Tinne Hoff Kjeldsen.

Last, but certainly not least, I sincerely thank my advisor, Karen Parshall. Thank you, Karen, for your faith in me and your boundless energy and inspiration.

Charlottesville, Virginia S. E. D.
July, 2002

To Michael,
meef

Chapter 1: A Defense of Journals as a Metric of Mathematical Development in Nineteenth-Century Britain

Perceptions of Nineteenth-Century British Mathematics

Historians have often characterized British mathematics of the early nineteenth century as depressed and insular.[1] Several British mathematicians of the period also shared this view, with the strongest expression of this view coming from Charles Babbage, who devoted his entire 1830 work, *Reflections on the Decline of Science in England and on Some of Its Causes*, to this theme.[2] In his "Introductory Remarks," Babbage stated that "[i]t cannot have escaped the attention of those, whose acquirements enable them to judge, and who have had opportunities of examining the state of science in other countries, that in England, particularly with respect to the more difficult and abstract sciences, we are much below other nations, not merely of equal

[1]These views about mathematics at Oxford, Cambridge, and Britain can be seen in John Fauvel, "800 Years of Mathematical Traditions," in *Oxford Figures: 800 Years of the Mathematical Sciences*, ed. John Fauvel, Raymond Flood, and Robin Wilson (Oxford: University Press, 2000), pp. 1-27 on p. 21; Ivor Grattan-Guinness, "Mathematics and Mathematical Physics from Cambridge, 1815-1840: A Survey of the Achievements and of the French Influences," in *Wranglers and Physicists*, ed. Peter Michael Harman (Manchester: Manchester University Press, 1985), pp. 84-110 on p. 84; and Morris Kline, *Mathematical Thought from Ancient to Modern Times* (New York: Oxford University Press, 1972), p. 622.

[2]See [John Playfair], "*Traité de Méchanique Céleste*," *Edinburgh Review* 11 (1807-1808): 249-284; John Toplis, "On the Decline of Mathematical Studies, and the Sciences Dependent on Them," *Philosophical Magazine* 20 (1805): 25-31; Charles William, Viscount Milton, *BAAS Report* 1 (1831): 15-17 on p. 16; "Preface," *Memoirs of the Analytical Society* (1813), reprinted in *Science and Reform: Selected Works of Charles Babbage*, ed. Anthony Hyman (Cambridge: University Press, 1989), p. 15; Sir Humphry Davy, quoted in Morris Berman, *Social Change and Scientific Organization: The Royal Institution, 1799-1844* (Ithaca: Cornell University Press, 1978), p. 68; and [Anonymous], "*The Principles of Fluxions, Designed for the Use of Students in the Universities*, by William Dealtry, B.D., F.R.S., late Fellow of Trinity College, Cambridge. 2d ed. Printed at Cambridge by J. Smith, printer to the University, 1816," *The Edinburgh Review* 27 (1816), p. 98, quoted in Mary Louise Gleason, *The Royal Society of London: Years of Reform, 1827-1847*, Harvard Dissertations in the History of Science, ed. Owen Gingerich (New York and London: Garland Publishing, Inc., 1991), p. 4.

rank, but below several even of inferior power."[3] To strengthen his claim, Babbage quoted John F.W. Herschel, who had declared that, in Britain, "whole branches of continental discovery are unstudied, and indeed almost unknown, even by name. It is in vain to conceal the melancholy truth. We are fast dropping behind. In mathematics we have long since drawn the rein, and given over a hopeless race."[4]

By 1870, however, the French geometer, Michel Chasles, painted for his countrymen a completely different picture of mathematical Britain:

> ...a mathematical society was founded in London in 1865 with a membership of one hundred, and this number is increasing; a society whose *Proceedings*, like those of the Royal Society of London,...publishes abstracts, more or less extended, of many papers. Is not [the existence of the *Proceedings of the London Mathematical Society*], which we applaud, an ingredient of future superiority in mathematical culture that should worry us?[5]

What happened to British mathematics in the space of only 40 years to produce these two profoundly different perceptions? To what extent do these contemporary perceptions hold true? Which factors enabled Britain, a country not quite at the mathematical forefront during the nineteenth century, to give us one of the first national mathematical societies in Europe or America (the London Mathematical Society)[6] as well as the pure and applied mathematical powerhouses of Arthur Cayley,

[3]Charles Babbage, *Reflections of the Decline of Science in England, and on Some of Its Causes* (London: B. Fellowes, 1830; reprint ed., New York: University Press, 1989), p. 1 (page citations are to the reprint edition).

[4]John F.W. Herschel, "Treatise on Sound," *Encyclopaedia Metropolitana* (1830); quoted in Babbage, p. ix.

[5]Michel Chasles, *Rapport sur les progrès de la géométrie* (Paris: Imprimerie nationale, 1870), pp. 378-379, quoted in Hélène Gispert, "The Effects of War on France's International Role in Mathematics, 1870-1914," in *Mathematics Unbound: The Evolution of an International Mathematical Community, 1800-1945*, ed. Karen Hunger Parshall and Adrian C. Rice (Providence: American Mathematical Society and London: London Mathematical Society, 2002) (Gispert's translation), pp. 105-121 on pp. 106-107.

[6]Adrian C. Rice, Robin Wilson, and Helen Gardner cite November 1866 as a date by which

James Joseph Sylvester, William Rowan Hamilton, Lord Kelvin, and George Gabriel Stokes?

Journals as Indicators of Academic Activity

Determining the loci of mathematical activity in nineteenth-century Britain is central to testing the validity of perceptions of early nineteenth-century mathematics like those of Babbage and Herschel and to tracing the evolution of mathematics in Britain throughout the nineteenth century. While British mathematical outlets certainly included correspondence, monographs, and encyclopedia articles, journals increasingly became the primary venue for scientific research and communication. In general, "periodicals became one of the nineteenth century's most characteristic products."[7] Roy Macleod has calculated that 100 new journals of all types were founded in Britain during the nineteenth century's second decade, and by its sixth, this number had risen to 170.[8] Scientific journals of four types — general and specialized, supported by scientific societies and established as commercial enterprises — also experienced remarkable growth in Britain during the nineteenth century.[9] As these

the London Mathematical Society (LMS) had reached national proportions. Other mathematical societies in Britain and on the Continent existed before this date but have been classified as amateur or student societies. One exception, the Amsterdam Wiskundig Genootschap, was operating at a national level by the early nineteenth century. Beckers has listed the Moscow Mathematical Society as following closely behind the LMS in 1867. Finland (1868), Bohemia (1869), France (1872), Denmark (1873), Italy (1884), the U.S. (1888), Hungary(1880s), and Germany (1890) also established such societies in the nineteenth century. Adrian C. Rice, Robin J. Wilson, and J. Helen Gardner, "From Student Club to National Society: The Founding of the London Mathematical Society in 1865," *Historia Mathematica* 22 (1995): 402-421 on p. 415; and Danny J. Beckers, "'Untiring Labour Overcomes All!' The Dutch Mathematical Society in European Perspective," *Historia Mathematica* 28 (2001): 31-47 on pp. 31, 40-44. For more on the amateur mathematical societies in Britain before the LMS, see chapter 2.

[7] Roy M. Macleod, "Macmillan and the Scientists," *Nature* 224 (1969): 428.

[8] *Ibid.*

[9] For more on the growth of these journals, see chapters 2 and 3.

scientific journals increased in number, their standing improved in response to the scientists' needs to disseminate results to a wide audience and to establish priority quickly.[10]

Mathematical articles appeared in British journals of all four of these types. One active British mathematical contributor and journal editor, James Whitbread Lee Glaisher, opined in 1880 that

> Perhaps in no branch of science is the literature of the subject so exclusively confined to periodical publications as in mathematics... Of course there are exceptions which will immediately occur to mathematicians... but, even when all the books published in all languages which are above the rank of school-books are included, they bear an extremely insignificant proportion to the amount of original mathematical literature contained in periodical publications; in fact it would be impossible to form any idea of the present state and extent of mathematical science from any study of the books upon the subject ... [T]he want of treatises is greatest in mathematics on account of the smallness of the audience addressed and the impossibility of expressing even the results in a manner intelligible to the non-mathematical reader. As a consequence of the scarcity of treatises there are many extensive branches of mathematics (such as, for example, the Partition of Numbers) which exist only in the periodicals...[11]

Looking back over a century after Glaisher, Hélène Gispert gave the following related characterization of journals in her study of French and Italian journals from 1860 to 1875: "[j]ournals, principal vectors of mathematical knowledge, play in effect a central role in the diffusion, thus in the evolution, of the movement of mathematics."[12]

---

[10]Arthur Jack Meadows, *Communication in Science* (London: Butterworth & Co., 1974), p. 67; and Bernard Houghton, *Scientific Periodicals: Their Historical Development, Characteristics and Control* (London: Clive Bingley, 1975), p. 12.

[11]James Whitbread Lee Glaisher, "Mathematical Journals," *Nature* 22(1880): 73-75 on p. 73.

[12]Hélène Gispert, "Une comparaison des journaux français et italiens dans les années 1860-1875," in *L'Europe mathématique: Histoires, Mythes, Identités*, ed. Catherine Goldstein, Jeremy Gray, and Jim Ritter (Paris: Fondation Maison des sciences de l'homme, 1996): 389-406 on p. 399. "Les journaux, principaux vecteurs du savoir mathématique, ont en effet un rôle central dans la diffusion, donc dans l'évolution, du mouvement des mathématiques."

Glaisher and Gispert both described a situtation to which mathematicians of today could readily relate. Synthesized, polished mathematical findings are found in books, but for the cutting-edge research, mathematicians turn to journals. As the remarks of Glaisher and Gispert indicate, the same was true of nineteenth-century mathematics. Using journals as the organizing principle of this dissertation, then, allows us to put our fingers on the pulse of nineteenth-century British mathematics.

While their opinions about the most effective metrics for measuring scientific development differ, sociologists, too, have argued that scientific papers are valuable indicators of scientific activity. For instance, Derek de Solla Price asserted that

> [t]he act of creation in scientific research is incomplete without publication, for it is publication that provides the corrective process, the evaluation, and perhaps the assent of the relevant scientific community... Private property in science is established by open publication; the more open the publication and the more notice taken of it, the more is the title secure and valuable... For reasons such as these, strongly built into three centuries of development of norms of scientific behavior, we must regard the end product of scientific research as the openly published scientific paper or its functional equivalent.[13]

Viewing scientific papers contained in scientific journals as significant indicators of research, we can consider scientists who authored or read and responded in print to papers in a given area within a given group of journals to constitute a *publication community*.[14] Limiting the articles to those on mathematics and the journals to those

[13]Derek de Solla Price, "Toward a Model for Science Indicators," in *Toward a Metric of Science: The Advent of Science Indicators*, ed. Yehuda Elkana *et al.* (New York: John Wiley and Sons, 1978), pp. 69-95 on p. 80. For other views from sociologists of science about the use of journals to trace the development of science, see Henry G. Small, "The Lives of a Scientific Paper," in *Selectivity in Information Systems: Survival of the Fittest*, ed. Kenneth S. Warren (New York: Praeger Science Publishers, 1985), pp. 83-97; Daryl E Chubin and Soumyo D. Moitra, "Content Analysis of References: Adjunct or Alternative to Citation Counting?," *Social Studies of Science* 5 (1975): 423-441; and David Edge, "Quantitative Measures of Communication in Science: A Critical Review," *History of Science* 17 (1979): 102-134.

[14]It would be reasonable to include within a *publication community* those who merely *read* the

published in Britain during the nineteenth century provides us with a valuable analytical tool with which to investigate the development of a *mathematical publication community* in nineteenth-century Britain.

Scientific Communities: Definitions and Studies

The focus of this dissertation, the nineteenth-century British mathematical publication community, might seem at first like an adjective-laden, unwieldy construct. However, it provides an alternative to other terms that would not be equally appropriate for investigating the development of British mathematics over the entire nineteenth century. As Steven Shapin and Arnold Thackray have warned, using terms like "scientific community" in their modern sense without any further definition or qualification "is to endanger the enterprise" of writing a history about time periods before around 1870.[15]

In considering eighteenth- and nineteenth-century British science, Shapin and Thackray gave a three-tiered definition of a scientific community. At the top is "the group of people who *published* a scientific paper, book or pamphlet. It seems defensible to regard the act of publishing one's thoughts or research as constituting a special level of identification with the scientific enterprise. Not all the people in this category are scientists (by *any* definition), but all individuals we are used to thinking of as scientists will be found on the publishing level."[16] Next are "those who did not publish but who formally and actively associated themselves with a scientifically-oriented

---

publications produced. Unfortunately, the mere readers — as opposed to actual writers — in the publication community are illusive and have not been considered here.

[15]Steven Shapin and Arnold Thackray, "Prosopography as a Research Tool in History of Science: The British Scientific Community 1700-1900," *History of Science* 12 (1974): 1-28 on p. 3.

[16]*Ibid.*, pp. 12-13 (their emphasis).

society or institution," and third are those who "patronized, applied or disseminated scientific knowledge or principles" but could not be placed in the two higher levels.[17]

In their study of the emergence of a mathematical research community in America from 1876 to 1900, Karen Parshall and David Rowe have defined a community as "an interacting group of people linked by common interests."[18] They have investigated factors in the emergence of a *research* community, including the establishment of universities oriented towards research, the foundation of a national mathematical society and publications devoted exclusively to research-level work, and the existence of researchers with the ability, desire, and encouragement to pass their knowledge on to future researchers.[19]

At our starting point here, 1800, many of the factors considered by Parshall and Rowe in the emergence of an American mathematical research community from 1876 to 1900 did not yet exist for British mathematics; moreover, the lack of specifically *mathematical* societies at a national level in Britain for the greater part of the nineteenth century makes the second criterion of Shapin and Thackray insufficiently precise to identify an appropriately specific group of mathematicians. Journals containing mathematics, however, were a constant feature in nineteenth-century Britain. This constancy suggests the potential fruitfulness of using journals to define a dynamic group of people engaged in mathematics, a *mathematical publication community* as

[17] *Ibid.*

[18] Karen Hunger Parshall and David E. Rowe, *The Emergence of the American Mathematical Research Community: 1876-1900: J.J. Sylvester, Felix Klein, and E.H. Moore*, HMATH, vol. 8 (Providence: American Mathematical Society and London: London Mathematical Society, 1994), p. xvi.

[19] *Ibid.*, pp. 429-431.

distinct from but containing a mathematical *research* community in the sense of Parshall and Rowe and complementary to a *scientific* community in the sense of Shapin and Thackray.

The idea of studying the development of fields of intellectual endeavor through journals is certainly not new. Journal publication has formed the focus of various studies in mathematics and other disciplines. Phillip George has examined English chemistry of the seventeenth and eighteenth centuries through the pages of the *Philosophical Transactions of the Royal Society*, and several studies have traced the nineteenth-century British literary and political scene through the *Edinburgh Review* and the *Athenaeum*.[20] In mathematics, the volume, *Messengers of Mathematics: European Mathematical Journals (1800-1946)*, "represents the first collection of papers devoted exclusively to the history of mathematical journals in relation to their individual communities."[21]

While these studies examined not only the articles themselves but also the wider social factors influencing the editors and contributors, none used journals to define a national community. That is the novelty of the present approach. Using every single mathematical contributor from a wide sample of British journals to define a

[20]Phillip George, "The Scientific Movement and the Development of Chemistry in England, as Seen in the Papers Published in the *Philosophical Transactions* from 1664/5 until 1750," *Annals of Science* 8 (1952): 302-322; Leslie Alexis Marchand, *The Athenaeum: A Mirror of Victorian Culture* (Chapel Hill: The University of North Carolina Press, 1941); and George Pottinger, *Heirs of the Enlightenment: Edinburgh Reviewers and Writers 1800-1830* (Edinburgh: Scottish Academic Press, 1992).

[21]Adrian C. Rice, "Review of *Messengers of Mathematics: European Journals (1800-1946)*," *Historia Mathematica* 25 (1998): 326-331 on p. 326. Elena Ausejo and Mariano Hormigòn, ed., *Messengers of Mathematics: European Journals (1800-1946)* (Madrid: Siglo XXI de España Editores, S.A., 1993).

mathematical publication community, this study casts a very wide net; tracking these contributors through the entire nineteenth century reveals profound developments in the mathematics itself as well as in the personal, disciplinary, financial, and political factors surrounding the production of this new knowledge.[22]

Never before considered through the lens of journal publication, national mathematical communities have been identified and studied from a number of other perspectives. Gispert has used membership in the *Société mathématique de France* to identify a community of French mathematicians, their mathematical production, and the institutional changes in which they were involved.[23] Kurt-R. Biermann employed the University of Berlin as the locus for his analysis of the educational and professional development of German mathematicians.[24] Similarly, Parshall and Rowe traced the emergence of an American mathematical research community largely through the formation of mathematical programs in American universities and the specific initiatives of some of their leaders, including J.J. Sylvester at the Johns Hopkins University and E.H. Moore at the University of Chicago.[25] The broader, publication-based criterion used here to define "community" in the context of nineteenth-century British mathematics gives us an innovative, comprehensive analytic tool; the development of the

[22]See Helena M. Pycior, "Internalism, Externalism, and Beyond: 19th-Century British Algebra," *Historia Mathematica* 11 (1984): 424-441; and Steven Shapin, "Discipline and Bounding: The History and Sociology of Science as Seen Through the Externalism-Internalism Debate," *History of Science* 30 (1992): 333-369 for summaries of arguments given for adopting a historical perspective that incorporates internal and external views.

[23]Hélène Gispert, *La France mathématique* (Paris: Société française d'histoire des sciences et des techinques and Société mathématique de France, 1991).

[24]Kurt-R. Biermann, *Die Mathematik und ihre Dozenten an der Berliner Universität, 1810-1933* (Berlin: Akademie-Verlag, 1988).

[25]Parshall and Rowe.

community, once identified, is traced by looking for factors similar to those used in these existing studies. Thus, our analysis can mesh well to effect comparative studies among different national mathematical communities.

Why Nineteenth-Century British Mathematics?

Mathematics underwent a period of explosive growth and development during the nineteenth century, witnessing the introduction of new methods, the development of disciplinary and interdisciplinary connections, and the evolution toward greater abstraction and generality. Moreover, the infrastructure of mathematics changed dramatically with the advent of the doctorate and the concomitant emphasis on the production of original research and the training of future researchers, the development of periodicals devoted exclusively to mathematics, and the creation of specialized mathematical societies.

Given, now, that the nineteenth century represents an exciting, dynamic period in the development of mathematics, why focus on nineteenth-century *Britain*? While France and Germany exchanged places as the number one and number two nineteenth-century mathematical powers, Britain remained a runner-up, yet, during the era of Isaac Newton, Britain had been recognized as a scientific leader. This raises the questions, why did Britain lose its leading position in mathematics and why did this position prove so hard to regain? While these questions cannot be answered categorically within the analytical framework of the present study, that framework does highlight the fact that many British mathematicians were painfully aware of their country's mathematical position relative to the Continent. National honor could be a powerful catalyst for these mathematicians. Without it, the stellar British mathematicians might have just abandoned their country's journals for more promising venues across the Channel. The rich variety of British journals publishing mathematics at all levels, including the research level, suggests that these mathematical leaders took a different course, a course that the following chapters will track.

Studies exist on a number of these British mathematical stars, as well as on the development of particular areas of mathematics in Britain, and British institutions for mathematical training. For example, Arthur Cayley, Augustus De Morgan, William Rowan Hamilton, James MacCullagh, James Joseph Sylvester, William Thomson (later Lord Kelvin), William Wallace, and William Whewell represent only a few of the nineteenth-century British mathematicians whose life and work have been investigated by historians.[26] Concerning mathematical fields, Harvey Becher, Marie-José Durand-Richard, John Dubbey, Elaine Koppelman, Maria Panteki, Helena Pycior, and Joan Richards have investigated the development of nineteenth-century British algebra and its relationship to other disciplines;[27] Dubbey, Phillip Enros, and Niccolò

[26]Tony Crilly, *Arthur Cayley, Mathematician Laureate of the Victorian Age*, to appear; Adrian C. Rice, "Augustus De Morgan and the Development of University Mathematics in London in the Nineteenth Century," (PhD dissertation, Middlesex University, 1997); Thomas Hankins, *Sir William Rowan Hamilton* (Baltimore, London: John Hopkins University Press, 1980); T.D. Spearman, "James MacCullagh," in *Science in Ireland 1800-1930: Tradition and Reform*, ed. John R. Nudds *et. al.* (Dublin: Trinity College Dublin, 1988), pp. 41-60; Karen Hunger Parshall, *James Joseph Sylvester: Life and Work in Letters* (Oxford: Clarendon Press, 1998); Crosbie Smith and M. Norton Wise, *Energy and Empire: A Biographical Study of Lord Kelvin* (Cambridge: University Press, 1989); Alex D.D. Craik, "Calculus and Analysis in Early 19th-Century Britain: The Work of William Wallace," *Historia Mathematica* 26 (1999): 239-268; and Harvey W. Becher, "William Whewell and Cambridge Mathematics," *Historical Studies in the Physical Sciences* 11 (1980): 1-48.

[27]Harvey W. Becher, "Woodhouse, Babbage, Peacock, and Modern Algebra," *Historia Mathematica* 7 (1980), 389-400; Marie-José Durand-Richard, "L'école algébrique anglaise et les conditions conceptuelles et institutionelles d'un calcul symbolique comme fondement de la connaissance," in *L'Europe mathématique*, pp. 447-477; John M. Dubbey, "Babbage, Peacock and Modern Algebra," *Historia Mathematica* 4 (1977): 295-302; Elaine Koppelman, "The Calculus of Operations and the

Guicciardini have considered the development of calculus in early nineteenth-century Britain;[28] Tony Crilly and Parshall have described the evolution of the nineteenth-century British approach to invariant theory;[29] and Richards has traced the direction of geometrical research in Victorian Britain.[30] Focusing on institutions, Rouse Ball provided a classic account of mathematics at Cambridge; Ivor Grattan-Guinness updated this account for 1815 to 1840; John Fauvel, Raymond Flood, and Robin Wilson considered the development of the discipline at Oxford; Adrian Rice surveyed nineteenth-century mathematics at London institutions; and Rice, Wilson, and Helen Gardner traced the birth and evolution of the London Mathematical Society.[31]

Rise of Abstract Algebra," *Archive for History of Exact Sciences* 8 (1971-1972): 155-242; Maria Panteki, "Relationships between Algebra, Differential Equations and Logic in England: 1800-1860," (PhD dissertation, London: C.N.A.A., 1992); Helena M. Pycior, "George Peacock and the British Origins of Symbolical Algebra," *Historia Mathematica* 8 (1981): 23-45, "Early Criticism of the Symbolical Approach to Algebra," *Historia Mathematica* 9 (1982): 392-412; and Joan L. Richards, "The Art and Science of British Algebra: A Study in the Perception of Mathematical Truth," *Historia Mathematica* 7 (1980): 343-365.

[28]John M. Dubbey, "The Introduction of the Differential Notation to Great Britain," *Annals of Science* 19 (1963): 38-48; Philip C. Enros, "The Analytical Society (1812-1813): Precursor of the Renewal of Cambridge Mathematics," *Historia Mathematica* 10 (1983): 24-47, "Cambridge University and the Adoption of Analytics in Early Nineteenth-century England," in *Social History of Nineteenth Century Mathematics*, ed. Herbert Mehrtens, Henk Bos, Ivo Schneider (Boston: Birkhäuser Verlag, 1981), pp. 135-148; and Niccolò Guicciardini, *The Development of Newtonian Calculus in Britain 1700-1800* (Cambridge: University Press, 1989) (despite his title's limitation of 1700-1800, Guicciardini also considers nineteenth-century developments).

[29]Tony Crilly, "The Decline of Cayley's Invariant Theory (1863-1895)," *Historia Mathematica* 15 (1988): 332-347, "The Rise of Cayley's Invariant Theory (1841-1862)," *Historia Mathematica* 13 (1986): 241-302; Karen Hunger Parshall, "Toward a History of Nineteenth-Century Invariant Theory," in *The History of Modern Mathematics*, ed. David E. Rowe and John McCleary, 2 vols. (San Diego: Academic Press, 1989), 1: 157-206; and *James Joseph Sylvester: Life and Work in Letters*.

[30]Joan L. Richards, *Mathematical Visions: The Pursuit of Geometry in Victorian England* (Boston: Academic Press, Inc., 1988).

[31]W.W. Rouse Ball, *A History of the Study of Mathematics at Cambridge* (Cambridge: University Press, 1889); *Oxford Figures*; Grattan-Guinness, "Cambridge;" Guicciardini; Adrian C. Rice, "Mathematics in the Metropolis: A Survey of Victorian London," *Historia Mathematica* 23 (1996), 376-417; Rice, Wilson, and Gardner; Adrian C. Rice and Robin J. Wilson, "From National to International Society: The London Mathematical Society, 1867-1900," *Historia Mathematica* 25 (1998): 185-217.

None of these studies, however, takes the long view; none provides a comprehensive study of mathematics and mathematicians over the entire nineteenth century. A study on William Thomson cannot, by design, say much about the nineteenth-century British approach to invariant theory, just as a study on Sylvester cannot say much about how the British approached thermodynamics. A study on Cambridge, by design, must ignore mathematicians outside the university sphere, just as a study of the London Mathematical Society must ignore those outside the Society's sphere. British mathematics had become sufficiently specialized in the nineteenth century to warrant studies on the British approach to specific mathematical fields and subfields, yet these types of studies, by design, cannot detect the myriad connections British mathematicians made *between* different mathematical areas. In short, these studies provide vivid snapshots of *parts* of the whole picture. The publication community provides an analytical framework within which to place, overlap, and interweave these individual components into a complex portrait of the British mathematical landscape during the nineteenth century.

The Nineteenth-Century British Mathematical Publication Community from Three Perspectives

Using the publication community as an analytical tool, we investigate the development of nineteenth-century British mathematics from three different yet complementary points of view. First, chapters 2, 3, and 4 trace the development and structure of society-supported, independent, and university-centered journals, respectively, which contained mathematical work. Specifically, they focus on the structure of journals and the goals of their financial backers, by isolating the factors that affected journal foundation, organization, operation, and specialization with respect to mathematics. The role of mathematicians and mathematics in this process offers a detailed view into the complex evolution of professionalization and stratification in British mathematics.[32] Who could publish mathematics in a given journal? What level did their articles have to attain and to what audience were they required to be directed? Who held the keys to the gateway of journal publication? To what extent did any gatekeepers, for that matter, exist? All of these questions, which the following chapters address, measure to what degree mathematicians were setting standards in journals that kept one group of authors out and encouraged another group to join in. Exclusion or acceptance in journals determined when, how, and if a mathematician's work could enter a major communication network; in this way, these standards played a powerful role in the certification process central to professionalization. Moreover, the existence of differing standards for different journals could indicate stratification.

[32]Here, professionalization entails the emergence of organizations, publications, and occupations that encourage and/or compensate mathematical research, and stratification refers to the process by which groups, made distinct through particular relationships to mathematics, communicate mathematical ideas through separate organizations and publications. Much has been written on both of these topics. On professionalization, see, for example, Nathan Reingold, "Definitions and Speculations: The Professionalization of Science in America in the Nineteenth Century," in *The Pursuit of Knowledge in the Early American Republic*, ed. Alexandra Oleson and Sanborn C. Brown (Baltimore and London: The Johns Hopkins University Press, 1976), pp. 33-69; Daniel J. Kevles, *The Physicists: The History of a Scientific Community in Modern America* (Cambridge, MA: Harvard University Press, 1987); Roy Porter, "Gentlemen and Geology: The Emergence of a Scientific Career, 1660-1920," *The Historical Journal* 4 (1978): 809-836; Peter Novick, *That Noble Dream: The "Objectivity Question" and the American Historical Profession* (New York: Cambridge University Press, 1988); Parshall and Rowe; and Dorothy Ross, *The Origins of American Social Science* (New York: Cambridge University Press, 1991). On stratification, see, for example, Jonathan R. Cole and Stephen Cole, *Social Stratification in Science* (Chicago: The University of Chicago Press, 1973); and David L. Roberts, "Albert Harry Wheeler (1873-1950): A Case Study in the Stratification of American Mathematical Activity," *Historia Mathematica* 23 (1996): 269-287. Hand-in-hand with professionalization and stratification is specialization. See John Higham, "The Matrix of Specialization," in *The Organization of Knowledge in Modern America, 1860-1920* ed., Alexandra Oleson and John Voss (Baltimore: The Johns Hopkins University Press, 1979), pp. 3-18.

Both of these processes are central to understanding the emergence of a mathematical research community in Britain as well as of parallel pedagogical and recreational mathematical communities.

Chapters 5 and 6 employ another lens to investigate the extent of professionalization and stratification by focusing on the members of the British mathematical publication community *per se.* Chapter 5 considers the domestic contributors, providing, through the use of prosopography, a profile that highlights mathematical training, locates mathematical centers, and considers the employment and scientific society involvement of this group of mathematicians. Because its subjects are determined solely by the fact that they published at least one mathematical article in one of a wide sample of British scientific journals, this prosopography considers active mathematicians, regardless of their professions or educational backgrounds. To what (if any) extent were these mathematicians paid to do mathematics? To which societies did they belong? What degrees and honors were available and desirable for them? This prosopography allows for a more conclusive answer to these questions so central to understanding the development of professionalization and stratification among nineteenth-century British mathematicians.

Internationalization, another key factor in professionalization in the sense of providing external validation, is considered in chapter 6. We first look at the foreign mathematical contributors to British journals (that is, the foreign members of the British mathematical publication community), focusing on the factors that encouraged them to send their articles over the Channel or the Atlantic. These factors give indications of international opinions about British mathematical journals, societies, and approaches to mathematics. We then look at the reciprocal group of nineteenth-century British mathematicians who published abroad and the circumstances that animated them to do so. Were British mathematicians emulated, appreciated, humored, or ignored abroad? Did international praise and attention matter to British mathematicians? The two reciprocal investigations in chapter 6 get to the heart of these questions and, in so doing, gauge the degree of Britain's insularity and isolation with respect to mathematics.

A third and final perspective rounds out the investigation of the nineteenth-century British mathematical publication community: the mathematical articles themselves. Through an analysis of the mathematics actually produced in the nineteenth-century British context, the intellectual contours of this publication community come more sharply into focus. Journal articles capture nineteenth-century mathematical developments in their initial form of presentation, while highlighting memorable, forgettable, and forgotten contributions, while revealing topics that contemporary mathematicians viewed as popular or important, while exploring the theorems and theories produced by British mathematicians, and while indicating trends of mathematical research in nineteenth-century Britain.

Categorizing these articles by mathematical area and tracking the popularity of these areas throughout the nineteenth century gives us a clearer sense the ebb and flow of mathematics during this period in Britain. Which areas did British mathematicians choose to emphasize? Which areas did they choose to neglect? What factors were behind these choices? Did these choices signal an awareness of international mathematical developments? The analyses in chapters 5, 6, and 7 allow us to address these questions not just by looking at the great discoveries of the "great men of mathematics" but also through the intellectual products, both great and small, of mathematical authors in a wide collection of British scientific journals. Without considering the mathematical products of what Thomas Kuhn has called "normal science," the picture of nineteenth-century British mathematics remains incomplete.[33] The everyday articles, in a sense, kept the mathematical fires burning. They fueled the communication of mathematical ideas. They were, just as much as any phenomenal mathematical breakthrough, nineteenth-century British mathematics.

These three foci — the journals, the mathematicians, and the mathematics — yield a multifaceted investigation of the structures, members, and products of the British mathematical publication community throughout the nineteenth century. Covering the entire nineteenth century gives us a long view of British mathematics; using the analytic tool of the publication community gives us a broad view of British mathematics; and analyzing this publication community from three complementary perspectives gives us a deep view of British mathematics. This length, breadth, and depth allow us to uncover technical and social factors in the evolution of a community from a comprehensive and innovative point of view. They yield a richer picture of the development of mathematics and mathematicians in nineteenth-century Britain.

[33]For a discussion of "normal science," see Thomas Kuhn, *The Structure of Scientific Revolutions*, 3rd ed. (Chicago and London: University of Chicago Press, 1996), especially pp. 23-42.

CHAPTER 2: *Transactions*, *Proceedings*, AND THE BRITISH MATHEMATICAL PUBLICATION COMMUNITY

From General to Specialized: an Overview of Nineteenth-Century British Scientific Societies and Their Journals

While the May 6, 1665 appearance of the first British scientific periodical, the *Philosophical Transactions of the Royal Society*, was predated by the first scientific journal, the French *Journal des Sçavans*, by three months, it adopted a format emulated by future scientific journals.[1] Henry Oldenburg, Secretary of the Royal Society, began the *Philosophical Transactions* as a private venture. The journal's foundation represented a natural extension of his duty to receive, announce, and reply to Society correspondence. While it was initially only affiliated with the Royal Society, the *Philosophical Transactions* finally gained official support from the organization by the mid-eighteenth century.[2] Since that time, the periodicals of British general societies have played a significant role in scientific discourse.

With the economic prosperity and urban growth of the Industrial Revolution surfaced a demand for scientific knowledge "as a form of rational amusement, as theological edification, polite accomplishment, technical agent, social anodyne, and intellectual ratifier of the new industrial order."[3] In response to this growing interest in science, new general scientific societies followed the Royal Society in founding journals near the end of the eighteenth century. The Royal Society of Edinburgh

[1]Bernard Houghton, *Scientific Periodicals: Their Historical Development, Characteristics and Control* (London: Clive Bingley, 1975), pp. 13-14.

[2]Arthur Jack Meadows, *Communication in Science* (London: Butterworth & Co., 1974), pp. 66-67.

[3]Jack Morrell and Arnold Thackray, *Gentlemen of Science: Early Years of the British Association for the Advancement of Science* (Oxford: Clarendon Press, 1981), p. 12.

and the Royal Irish Academy, both of which began publishing their *Transactions* in the 1780s, emerged in established seats of the United Kingdom while "Literary and Philosophical" societies and their journals were founded in burgeoning industrial towns.[4] In addition to these new societies, the 1831 establishment of the British Association for the Advancement of Science (BAAS) and its *Report* promoted agendas of science throughout Britain.

Just as general scientific societies had differentiated themselves from general learned journals throughout the eighteenth century,[5] specialized societies began to flourish in the early nineteenth century. In fact, by 1844, there were ten specialized scientific societies publishing journals in London alone.[6] With the growth of these societies, the supremacy of general science society journals waned: general science journals grew from seven in 1800 to 22 in 1900, while British specialized science journals grew from three to at least 67 during the nineteenth century.[7] British mathematical societies

[4]These provincial literary and philosophical societies included: Manchester (f. 1781, *Memoirs* f. 1785), Newcastle upon Tyne (f. 1793, *Report* f. 1793), Birmingham (f. 1800, *Proceedings* f. 1876), Glasgow (f. 1802, *Proceedings* f. 1841), Liverpool (f. 1812, *Report and Proceedings* f. 1844), Plymouth (f. 1812, *Report and Transactions* f. 1862), Leeds (f. 1818, *Transactions* f. 1837), Cork (f. 1819), York (f. 1822, *Annual Report* f. 1824), Sheffield (f. 1822, *Annual Report* f. 1824), Whitby (f. 1822, *Report* f. 1824), Hull (f. 1822, *Report* f. 1864), and Bristol (f. 1823).

[5]Robert Mortimer Gascoigne, *A Historical Catalogue of Scientific Periodicals, 1665-1900* (New York: Garland Publishing, Inc., 1985), p. 118.

[6]*Ibid.*, pp. 3-89. The disciplines of these societies and the dates of the foundation of their journals were natural history (1788), geology (1807), horticulture (1810), astronomy (1821), geography (1832), zoology (1833), and entomology (1834), statistics (1835) (listed here although Gascoigne did not include statistics in his study), chemistry (1841), and microscopy (1844). Beyond the metropolis, Gascoigne lists eight British specialized societies with journals during this period. The disciplines of these societies were geology, natural history, and botany. Morrell and Thackray count five general and 25 specialized science societies in the metropolis by 1850 (up from two general and two specialized in 1780); in the provinces for 1850, they count 30 general and 42 specialized science societies in the provinces (up from none of either category in 1780). Morrell and Thackray, p. 546.

[7]Gascoigne, pp. 132-170. The specialized journals listed concerned mathematics, astronomy, physics, chemistry, geology, geography, natural history, botany, zoology, and experimental biology. This trend occurred throughout Europe. According to Gascoigne, "while the numbers of general science periodicals grew more or less steadily from the seventeenth century to 1900 their proportion

arrived relatively late in contrast to those of other disciplines. However, by the 1880s, mathematics researchers and teachers could claim three societies and their journals devoted to their discipline.

The journals of scientific societies provided opportunities as well as limitations to the British mathematical publication community. This chapter examines the development of the formats of these journals as well as the criteria by which papers were judged. In the case of the societies not exclusively devoted to mathematics, the chapter discusses the role of mathematicians as officers, referees, and publishing members. It also considers how the foundation of mathematical societies and their journals reflected agendas of professionalization and pedagogical policies among British mathematicians.

Fit to Print? The Evolution of Refereeing in General Scientific Society[8] Journals

As the first journal of its kind in Britain, the *Philosophical Transactions* and its publication procedures set a standard for other scientific societies to follow. Although "the printing of... [the *Transactions*] was always, from time to time, the single act of the respective Secretaries"[9] for its first 46 volumes, the *Transactions* became the official journal of the Society in 1752. Along with the journal's new official status, the

among scientific periodicals of all types decreased from 100% in 1770 and earlier to 27% in 1900," *Ibid.*, p. 131.

[8]This chapter will focus on four general scientific societies: the Royal Society of London, the Royal Society of Edinburgh, the Royal Irish Academy, and the Manchester Literary and Philosophical Society. While these four form only a sample of Britain's nineteenth-century general scientific societies, they are among the most prominent. Gascoigne lists the primary journals of these four societies as Britain's chief periodicals beginning before 1790. *Ibid.*, p. 93.

[9]Advertisement to the *Philosophical Transactions*, volume 47; quoted in *The Record of the Royal Society, 1897* (London: Harrison and Sons, 1897), p. 103.

Royal Society Council created the Committee of Papers, a group of Council members that managed the selection, editing, and publication of papers in the *Philosophical Transactions*.[10] The Society's statutes of 1752 state that this Committee "shall be at liberty to call in to their assistance... any other members of the Society who are well skilled in any particular branch of Science that shall happen to be the subject-matter of any paper which shall be then to come under deliberation."[11] This referral option, however, was at best an informal process during the eighteenth century:

> the earliest mention which has been found in the Society's records of a paper being technically 'referred' is on May 25, 1780, when a paper by Mr. Ludlow as 'referred to Mr. Cavendish and Dr. Hutton.' There does not appear to be a similar record until March 21, 1831, when a paper by Prof. Davy was referred to Mr. Faraday.[12]

While it eschewed formal refereeing procedures, the Committee of Papers was hampered in judging the quality of papers accurately because of the lack of scientific training of its members.[13] Moreover, the state of the Committee of Papers failed to improve during the over 40-year tenure of Sir Joseph Banks as President of the Royal Society; the controlling body of the *Philosophical Transactions* "had devolved into a perfunctory clearing house and a sometime arbitrary decision maker."[14]

---

[10]Sir Henry Lyons, *The Royal Society, 1660-1940* (Cambridge: University Press, 1944), p. 253. The Royal Society's officers and vice-presidents were made permanent members of this committee. For the Royal Society as well as other British scientific societies, a paper could be submitted directly if the author was a member of the society or could be "communicated" through a member. Dwight Atkinson, *Scientific Discourse in Sociohistorical Context: The Philosophical Transactions of the Royal Society of London, 1675-1975* (Mahway, NJ: Lawrence Erlbaum Associates, 1999), p. 43.

[11]Royal Society statues of 1752; quoted in *Record*, p. 104.

[12]*Record*, p. 104.

[13]Lyons, p. 253.

[14]Mary Louise Gleason, *The Royal Society of London: Years of Reform, 1827-1847*, Harvard Dissertations in the History of Science, ed. Owen Gingerich (New York: Garland Publishing, Inc., 1991) p. 246.

A call for change in the execution of the *Philosophical Transactions* became part of a wider reform movement which began after the Banks's death in 1820. In one of the most potent tracts devoted to the Society's reform during this period, Augustus Bozzi Granville called for the Committee of Papers to be restructured. Granville, a Fellow of the Society and an Italian ex-patriot, described the Committee's administrative faults in his 1830 anonymous pamphlet, *Science Without a Head, or, The Royal Society Dissected*:

> In proportion as we get nearer to our own times, the importance of the papers rejected seems to be in the inverse ratio of the scientific character of the deciding members of the committee; — and subsequent events have proved that those members have as often decided wrong when they decided for the rejection of papers — as they would have decided right had they not admitted some of the papers which appear now in the Transactions, but which are fit only for insertion in magazines and other periodical publications.[15]

Granville suggested that the fellowship of the Society be divided into classes by disciplines, including a "Free Class" for non-scientific fellows, and that each class should be responsible for the selection of papers in its respective discipline.[16] This plan would ensure that a paper's judges would be well-versed in its subject; it also excluded non-scientific members from the referral process entirely.

While Granville's plan to separate the fellows by discipline was not adopted by the Society, his call for the reform of the publication procedures of the *Philosophical Transactions* received attention.[17] The Duke of Sussex used his second presidential

[15] Augustus Bozzi Granville, *Science Without a Head; or, The Royal Society Dissected* (London: T. Ridgway, 1830), pp. 57-58.

[16] Gleason, pp. 247-248.

[17] Granville's idea of the use of distinct groups, separated by discipline, to consider the publication of papers was instituted in 1838. These Sectional Committees in "astronomy, chemistry, geology

address to the Royal Society to outline an 1832 Council resolution crafted in order to "increase the usefulness and to uphold the credit of the Royal Society; I mean the Resolution ... to allow no Paper to be printed in the Transactions of the Royal Society, unless a written Report of its fitness shall have been previously made by one or more Members of the Council, to whom it shall have been especially referred for examination."[18] Besides citing the refereeing practices of continental societies, the Duke's justification of the Society's new resolution described referees "as a powerful stimulus to the exertions of the genuine cultivators and lovers of science, who feel assured that their labours will be properly examined and appreciated by those who are most competent to judge of their value; whilst at the same time, they tend to keep under the obtrusive and turbulent pretensions of those who presume to claim a rank as men of science, for which they possess no just title or qualification."[19] With this council resolution, referee's reports became part of the *modus operandi* of the publication of the Royal Society's journals.[20]

Other British general scientific societies adopted refereeing procedures which were

---

and mineralogy, mathematics, physics and 'Physiology, including the Natural History of organized beings'... were entrusted with making recommendations for the Royal and Copley Medals, as well as with the refereeing of papers submitted, all of which rendered them very powerful. The 'modern' system, did not... work very smoothly in the mid-nineteenth century, and the Physiological Committee in particular was to appear so biassed that the system broke down ten years later." Marie Boas Hall, *All Scientists Now: The Royal Society in the Nineteenth Century* (Cambridge: Cambridge University Press, 1984), p. 69. In 1896, these Sectional Committees were resurrected "and have continued in increasing number ever since." *Ibid.*, p. 126.

[18]Duke of Sussex, "Address Delivered before the Royal Society," *Abstracts of the Papers Printed in the Philosophical Transactions of the Royal Society of London* 3 (1830-1837): 140-155 on p. 141.

[19]*Ibid.*, p. 142.

[20]The refereeing process adopted by the Royal Society continued to evolve throughout the nineteenth century. For example, as late as 1898, "it was agreed that the names of paper referees would no longer be kept in the Society journal book, thereby ensuring the anonymity of reviewers." Atkinson, p. 44.

variants of the several versions followed by the Royal Society of London. From the first volume of the Royal Society of Edinburgh's *Transactions*, for example, the Council selected the papers for publication. By at least the mid-nineteenth century,[21] this body began appointing " 'members conversant with the subject' to act as referees."[22] For the Manchester Literary and Philosophical Society, the concept of a council was synonymous with a group who would select papers for publication. In fact, the original name of the Society's leadership group was the Committee of Papers.[23] This body decided which papers to publish in the Society's *Memoirs* and even "select[ed] parts of a paper for publication if the whole be deemed unsuitable."[24] While it automatically included the society's officers, the fourteen-member Committee also included six members of the Society outside of the ruling circle.[25]

While scientific societies employed refereeing committees in order to provide a more objective system in which to evaluate papers, these groups were not always capable of recognizing outstanding submissions. For example, as a result of the Royal Irish Academy's refereeing practices, "probably the most significant contribution ever submitted to the Academy was at first rejected."[26] In 1824, Henry H. Harte, Dionysius

---

[21]While they do not give exact dates for the establishment of referees, Campbell and Smellie list James Clerk Maxwell (1831-1879) and Charles Piazzi Smyth (1819-1900) as active referees. Neil Campbell and R. Martin S. Smellie, *The Royal Society of Edinburgh (1783-1983): The First Two Hundred Years* (Edinburgh: The Royal Society of Edinburgh, 1983), p. 32.

[22]*Ibid.*

[23]Robert H. Kargon, *Science in Victorian Manchester: Enterprise and Expertise* (Baltimore: The Johns Hopkins University Press, 1977), p. 7. This body's duties also included adjudicating the awards and premiums set by the Society. It assumed the name "Council" in 1822. *Ibid.*, pp. 7, 14.

[24]*Ibid.*, p. 7.

[25]*Ibid.*

[26]R. B. McDowell, "The Main Narrative," in *The Royal Irish Academy: A Bicentennial History 1785-1985*, ed. T. Ó. Raifeartaigh (Dublin: The Royal Irish Academy, 1985), pp. 1-92 on p. 27.

Lardner, and a Dr. MacDonnell were assigned by the Academy to evaluate a paper on optics by a Trinity College, Dublin undergraduate. In their report of the paper submitted in June of 1825, the committee wrote

> that the results at which the author has arrived are novel and highly interesting, and that considerable analytical skill has been manifested in the investigations which lead to them. But we conceive that the discussions included in the Memoir are of a nature so very abstract, and the formulæ so general, as to require that the reasoning by which some of the conclusions have been obtained should be more fully developed, and that the analytical process by which some of the formulæ have been obtained should be distinctly specified. This we conceive to be necessary in order to render the publication of the Memoir generally useful.[27]

Although probably not happy with these opinions, the young author, William Rowan Hamilton, rewrote and expanded his original work, "On Caustics," and resubmitted it two years later to the Academy as "Theory of Systems of Rays."[28] This enlarged paper, in the opinion of Hamilton's first biographer, Robert Percival Graves, "became the foundation of his mathematical fame."[29]

The referees' reports of mathematical fellows of the Royal Society also provide examples of mathematicians upholding the quality and defining the place of mathematics in general science society journals. By defining what was publishable, mathematical referees established limits on the style and depth of mathematics published in the Royal Society's journals. James Whitbread Lee Glaisher expressed his ideas late in 1889 about the type of mathematics most suitable for the journals of the Royal

[27]Referees' Report, Henry H. Harte, Dionysius Lardner, and Doctor MacDonnell, 13 June 1825; quoted in Robert Perceval Graves, *Life of Sir William Rowan Hamilton* (Dublin: Hodges, Figgis, & Co., 1882), pp. 186-187.

[28]William Rowan Hamilton, "Theory of Systems of Rays," *Transactions of the Royal Irish Academy* 15 (1828): 69-174.

[29]Graves, p. 187.

Society when he refereed a paper on linear differential operators by Edwin Bailey Elliott, Fellow at Queen's College, Oxford:

> My doubt has been whether the subject of the paper was not somewhat too technical for the Phil. Trans. – as I have always felt that the papers in the Phil. Trans. should deal with the broad lines of methods or with results of striking interest, rather than with points of mathematical detail, no matter how important.[30]

However, after finding that "its technicality is rather in the form than in the subject," Glaisher recommended Elliott's paper for publication in the *Philosophical Transactions.*[31]

Glaisher again voiced his opinions about mathematics published in the *Philosophical Transactions* when he rejected Francis Edgeworth's "The Asymmetrical Probability Curve" in 1895.[32] In his report, Glaisher remarked that "[t]he subject of the paper is difficult and interesting; and, so far as I can see, the treatment is sound. But the question discussed is not in my opinion, sufficiently large in scope or important in character to form the subject of a paper in the Phil. Trans... It seems to me that it would be suitable for publication in a mathematical journal, but rather out of place in the Phil. Trans."[33]

Besides concerns about the quality and technicality of a mathematical paper,

---

[30] Referee's Report, James Whitbread Lee Glaisher, 28 Dec. 1889, Royal Society Archives, London, R.R.100.260.

[31] Glaisher's earlier comments must have made a strong impression on the Secretary, Lord Rayleigh, because only an abstract of Elliott's paper was published in the *Proceedings.* Edwin Bailey Elliott, "On the Interchange of the Variables in Certain Linear Differential Operators (Abstract)," *Proceedings of the Royal Society of London* 46 (1889): 358-362.

[32] Edgeworth was at that time the Drummond Professor of Political Economy at Oxford. *J.C. Poggendorff's Biographisch-Literarisches Handwörterbuch* (Leipzig: Johann Ambrosius Barth, 1904), s.v. "Edgeworth, Francis Ysidro."

[33] Referee's Report, James Whitbread Lee Glaisher, 15 May 1895, Royal Society Archives, London, R.R.12.97.

Royal Society politics could influence the outcome of a referee's report. In 1848, George Peacock refereed a paper by Augustus De Morgan which considered the *Commercium epistolicum*, a 1712 Royal Society report concerning the Newton-Leibniz calculus controversy. De Morgan exposed changes to the second edition of the report, published 13 years later, which "hardened the language of the report against Leibniz, making it appear to accuse him of plagiarism."[34] In his referee's report to Samuel Hunter Christie, Peacock did not dispute the truth of De Morgan's paper and classified its author as "the most accurate & learned of all modern writers on the History of Mathematics."[35] However, Peacock believed that "if the question of repairing a wrong done 140 years ago be entertained it must be entertained in a much more formal & solemn manner: I should recommend therefore Mr. De Morgan to withdraw his Paper & to publish it through some other channel than the RST[ransactions]."[36] The referee actually suggested another channel, but he indicated that this further measure would not give De Morgan any satisfaction:

> [I]f he thinks that the question should be entertained by the Council, then a distinct application should be made to the Council for this purpose. If however such an application should be made to the Council, I should not recommend the Council to entertain it... the Council as a body would appear to me to act wisely in abstaining from the expression of any official opinions whatever affecting the acts either of contemporaries or predecessors.[37]

The Royal Society had expressed earlier an entirely different attitude when it printed

[34] Adrian C. Rice, "Augustus De Morgan: Historian of Science," *History of Science* 34 (1996): 201-240 on p. 215.

[35] Referee's Report, George Peacock to Samuel Hunter Christie, 16 Oct. 1847, Royal Society Archives, London, R.R.1.57.

[36] *Ibid.*

[37] *Ibid.*

in its *Philosophical Transactions* De Morgan's first paper on the *Commercium epistolicum* which "actually cleared up a point in favour of Newton."[38] However, when De Morgan put Leibniz in a more favorable light, his work was relegated to the archives of the Royal Society instead of the pages of one of its journals.[39]

In addition to reflecting Society politics, referees provided commentary on their colleagues. In reporting on Cayley's "On the Porism of the In-And-Circumscribed Polygon," Phillip Kelland gave an "undoubtable opinion that it ought to be printed."[40] However, he expressed frustration with being unable to connect the geometrical ideas of the problem[41] with Cayley's analysis of it, remarking that,

> Mr. Cayley appears to me to be one of those who are powerful in throwing out blocks for the next generation to work up. Their present value would be increased a hundred fold, were some fragments from them chiselled and made *fit* for ordinary hands."[42]

As the above examples show, the refereeing process gave mathematical members of scientific societies active roles in controlling the content and quality of the mathematics published in their societies' journals. While not free from society politics, mathematical referees could guide and encourage the research in their discipline.

[38]Rice, "De Morgan," p. 213. In this paper, De Morgan pointed out that although it was thought to have been entirely British, the committee that wrote the *Commercium epistolicum* included two continental members. *Ibid.*, pp. 213-214. Augustus De Morgan, "On a Point Connected with the Dispute between Keill and Leibnitz about the Invention of Fluxions," *Philosophical Transactions of the Royal Society of London* 136 (1846): 107-109.

[39]Rice, "De Morgan," p. 214. De Morgan's paper eventually found a home in the *Philosophical Magazine*. *Ibid.*, p. 215.

[40]Referee's Report, Phillip Kelland, 27 May 1861, Royal Society Archives, London, R.R.4.45.

[41]The problem involved finding conditions for two conics such that "a polygon may be inscribed in the one, and circumscribed about the other conic, in such a manner that any point whatever of the circumscribing conic may be taken for the vertex of the polygon." Cayley had given a general formula for this problem in 1853, but sought in this paper to put the relationships between the conics in a "new and simple form." Arthur Cayley, "On the Porism of the In-And-Circumscribed Polygon," *Philosophical Transactions of the Royal Society of London* 151 (1861): 225-239 on p. 225.

[42]Referee's Report, Phillip Kelland, 27 May 1861, Royal Society Archives, London, R.R.4.45. Kelland's emphasis.

These referees could also set the limits on the type and depth of mathematics appearing in a specific society journal. For better or worse, this subset of members of the mathematical publication community helped build and keep the gates guarding the journals in which publication led to distinction.

Octavo Outrunning Quarto: Secondary Journals of General Scientific Societies

While competent refereeing procedures evolved to ensure the quality of papers published in society journals, the widening of society publication venues rescued many papers, which earlier would have remained unpublished despite the quality of the results contained in them. In his tract, *The Royal Society in the XIXth Century,* Granville lamented that in the case of the Royal Society, the author of a rejected paper lost not only the opportunity to publish in the *Philosophical Transactions* but also his original memoir; this document remained in the Society's archives.[43] Charles Babbage, a mathematical Fellow whose *Reflections of the Decline of Science in England* along with Granville's text pushed for the Royal Society's reform, also recognized a need to widen the publication venue of the Royal Society. Specifically, he believed the Society should publish information about the actions of the Council, the adjudication of medals, and admissions and deaths among the Society's fellowship.[44] Babbage also advocated the publication of abstracts to papers that had appeared in the *Philosophical Transactions* in order to increase the circulation of the ideas

[43]Augustus Bozzi Granville, *The Royal Society in the XIXth Century* (London: Printed for the Author, 1836), p. 131. An author could appeal to the Society for permission to make a copy (at his expense) of his archived work. *Ibid.*

[44]Charles Babbage, *Reflections of the Decline of Science in England, and on Some of Its Causes* (London: B. Fellowes, 1830; reprint, New York: New York University Press, 1989), pp. 97-99 (page citations are to the reprint edition).

contained within them and to present them in a more streamlined form: "[p]erhaps two or three volumes octavo, would contain all that has been done in this way during the last century."[45]

The concerns of both Granville and Babbage were addressed in 1832 with the establishment of the *Abstracts of the Papers Printed in the Philosophical Transactions of the Royal Society of London.* While the title of this new journal aptly described the content of its first two volumes,[46] by its third volume, the journal had added accounts of Society business in addition to abstracts of papers never published in the *Philosophical Transactions*[47] and the "President's address at the Anniversary Meeting[,]... a report by the Council and senior Secretary, a list of Fellows deceased (with eulogies of the more important) and medal awards."[48] A change of title to *Abstracts of the Papers Communicated to the Royal Society* in the fifth volume, published in 1851, reflected the growing use of the journal as a repository for results overlooked by the *Philosophical Transactions.* The change of the journal's title to the familiar *Proceedings of the Royal Society* in 1856 also heralded further changes in the format of the publication. As the 1897 *Record* of the Royal Society explained,

> [m]any papers were published in full in this and the subsequent volumes which were not published in the 'Philosophical Transactions' at all. These papers were for many years only the briefer or less important communications, the more bulky or more valuable papers being reserved for the quarto form. In time even this distinction became less marked, some papers of great importance appearing only in the 'Proceedings.'[49]

[45] *Ibid.*, p. 100.
[46] Volume 1 contained abstracts to papers printed in the *Philosophical Transactions* from 1800 to 1814, and volume 2 covered the papers from 1815 to 1830.
[47] *Record*, p. 165.
[48] Hall, p. 67.
[49] *Record*, p. 165. Atkinson provided further consequences of the presence of the *Proceedings* as a

The Royal Society of Edinburgh, the Royal Irish Academy, and the Manchester Literary and Philosophical Society soon followed the lead of the Royal Society of London and added *Proceedings* to their publication offerings. The *Proceedings of the Royal Society of Edinburgh* first appeared in 1832, and, like its London counterpart, represented a publication forum for shorter articles, society news, and obituaries.[50] The *Proceedings* of the Royal Irish Academy, in " 'dumpty' octavo" form,[51] commenced four years later and helped shorten the delay between the receipt and publication of papers read to the Academy.[52] This new journal eventually eclipsed the Academy's *Transactions*; in fact, high publication costs induced the society to end the production of its original journal in 1917, and the *Proceedings*, "with a slightly enlarged page, became the medium by which the Academy's papers were regularly published."[53] Similarly, the *Memoirs* of the Manchester Literary and Philosophical were combined with its *Proceedings* in 1888, only 30 years after the secondary journal's foundation.

With the emergence and development of *Proceedings*, British mathematicians

---

journal venue for the Royal Society. In comparing submission records of the Royal Society for 1874-76 to those of 1824-26, he found that during the later period, many more papers were being published. "[T]he *Proceedings* was now publishing the lion's share of submissions to the Society, outdistancing the PTRS by approximately three-to-one; and ... many fewer papers were being rejected than had been earlier in the century, when the PTRS was the only vehicle of Royal Society publication. Thus, whereas about 23% of the papers considered for publication had been rejected in 1824-1826, only 10% fell into this category from 1874-1876." Atkinson, p. 43.

[50]Campbell and Smellie, p. 33.

[51]McDowell, p. 32.

[52]T.D. Spearman, "Mathematics and Theoretical Physics," in *The Royal Irish Academy: A Bicentennial History*, ed. T. Ó Raifeartaigh, (Dublin: The Royal Irish Academy, 1985), pp. 201-239 on p. 207. While even critics of the Royal Society, namely Charles Babbage, praised the regularity and speed with which the early nineteenth-century volumes of the *Philosophical Transactions* were published (see Babbage, p. 97), the *Transactions* of the Royal Irish Academy appeared irregularly. From 1800 to 1831, only ten volumes of the journal appeared, with delays between subsequent volumes as great as seven years.

[53]McDowell, p. 56.

could more easily publish their work under the aegis of their scientific societies. A short but significant mathematical talk, a notice of work in progress, or an exploratory probe could now proceed directly to a society publication organ instead of being resubmitted to an independent journal. In this way, mathematicians could participate more fully in the publication function of their societies, which communicated research beyond the walls of a meeting room to the wider British mathematical publication community. Central to any establishment of precedents or changes in the procedures of society journals were the leaders of these societies. Thus, the widening of the British general scientific societies' publication venues described in this section represented a recognition by the leaders of these societies of the changing research needs of British scientists. As the next section shows, mathematicians formed a substantial part of this leadership and worked for the advancement of their societies as well as their discipline.

Running the Show: Mathematical Officers in General Scientific Societies

As the most visible office in scientific societies, the presidency provided an outlet for the promotion and recognition of mathematics. The Royal Society of London narrowly missed having a mathematical President in 1830. John Frederick William Herschel had served as a Sectretary of the Society for two years before resigning and joining in the reform efforts that followed Sir Joseph Banks's death. Herschel had served under Banks's successor, Sir Humphry Davy, in a Society administration balanced between "rich men and men of rank."[54] Herschel tendered his resignation

[54]Roy M. MacLeod, "Whigs and Savants: Reflections on the Reform Movement in the Royal Soci-

after Davies Gilbert succeeded Davy as President and subsequently ended a Council inquiry regarding the reform of the Society's electoral procedures.[55] Two years later, wary of growing discontent concerning his presidency, Gilbert decided to leave his post and picked as his successor the Duke of Sussex.[56] In response, the reform-minded fellows put Herschel forward as an opposing presidential candidate. While committed to addressing the problems of the Society, Herschel did not personally seek this office; writing four days before the election to Charles Babbage, Herschel stated "I do *not* desire the Presidency – I am not a *Candidate*– If placed in the Chair I will sit there one year and work if not I shall be *more* than *content*."[57] In a heated election that forced members to choose between a patron and a practitioner of science as President of the Royal Society, Sussex won by eight votes. While this outcome was seen at the time by reformers as a blow to British science, it challenged the traditional relationship between the Society's leadership and its fellows.[58]

By the 1860s, the choice of who would fill the Royal Society's highest office depended on scientific stature instead of prestige or title: "[t]he President of the Royal Society had become an acknowledged leader of science in Britain, so that the position not only was one of power but also a recognition of scientific, rather than, as earlier, of worldly, success."[59] Under these new qualifications, three luminaries of pure and

ety, 1830-1848," in *Metropolis and Province*, ed. Ian Inkster and Jack Morrell (London: Hutchinson & Co., 1983), pp. 55-90 on pp. 61-62.

[55]Atkinson, p. 36.

[56]Sussex was "brother to the new King, William IV. Educated at Göttingen, his liberal and cosmopolitan credentials were impecable." MacLeod, p. 84.

[57]John Herschel to Charles Babbage, 26 Nov. 1830; quoted in Gleason, p. 296.

[58]MacLeod, pp. 65-66.

[59]Hall, p. 145.

applied mathematics served as President during the majority of the last quarter of the nineteenth century: William Spottiswoode,[60] George Gabriel Stokes, and William Thomson (from 1892, Lord Kelvin).[61]

Thomson's Royal Society presidency interrupted a presidency he was already serving at the Royal Society of Edinburgh. Although the Edinburgh society had decided in 1860 to limit its presidents' tenures to five years, Thomson served three non-consecutive terms in the highest office for a total of 21 years.[62] The high opinion for Thomson in Edinburgh may be partly explained by the caliber of his contributions to its Society's journals. Sir James Alfred Ewing, Society President from 1924 to 1929 believed that "[n]o other contributor has done so much to give our publications a world-wide and lasting fame."[63]

Of all the general scientific societies considered in this chapter, the Royal Irish Academy had the highest percentage of mathematicians among its nineteenth-century presidents (see Table 2A). Moreover, these eight mathematicians served as President for over half of the century. All of the members of this mathematical dynasty worked as professors at Trinity College, Dublin.[64] For the mathematical center of Trinity

[60]Spottiswoode became President of the Royal Society in 1878, after serving for two years as Treasurer. In 1870, he had served as the President of the London Mathematical Society and was a member of the small, informal group of leading late nineteenth-century British scientists called the X Club. In his first presidential address, Spottiswoode announced new procedures for publishing papers that would speed the publication of the *Proceedings* and streamline the abstracting of papers. Spottiswoode served as Royal Society President until his death on 27 June 1883. Hall, pp. 117-118.

[61]With his five-year tenure as President beginning in 1885, Stokes spent in all 25 years as a Society officer. Kelvin succeeded his close friend Stokes and also served as President for five years. Hall, p. 124.

[62]Campbell and Smellie, p. 13. Thomson served from 1873 to 1878, 1886 to 1890, and 1895 to 1907.

[63]Sir James Alfred Ewing; quoted in *ibid.*, pp. 47-48.

[64]John Brinkley (President: 1822-1835) and William Rowan Hamilton (1837-1846) held chairs in astronomy; Bartholomew Lloyd (1835-1837), Charles Graves (1861-1866) held chairs in mathematics;

College, the Academy served as a venue for publications as well as an outlet for society activity.

While the office of President allowed mathematicians to be the most visible members of their societies, other society posts placed mathematicians in close contact with society publications. In particular, the secretaries of these societies often had the responsibility of editing their societies' journals.[65] In the case of the Royal Society, Stokes has been considered "if possible, the most hard-working of all nineteenth-century Secretaries."[66] The effort that Stokes put into Society correspondence induced Michael Foster, a physiologist and later Society Secretary, to remark that "[i]t has been painful to see how his energy has been wasted in this way."[67] Much of this correspondence concerned Stokes's editorial duties and represent Stokes as an arbitrator between the referees and authors of papers.

One author particularly disgruntled by the referee's report of his paper was Thomas Penyngton Kirkman. After rejecting a career in his father's cotton business, Kirkman supported himself through private tutoring and earned a BA from 52-year career as rector of the parish at Croft. This parochial life enabled him to devote much time to mathematics, an avocation that began in response to a prize question Kirkman read

Bartholomew Lloyd also, along with his son Humphrey Lloyd (1846-1851), and John Hewitt Jellett (1869-1874) held chairs in natural and experimental philosophy; Thomas Romney Robinson (1851-1856) held a physics professorship; Samuel Haughton (1886-1891), reflecting his multidisciplinary interests, held a chair in mineralogy and geology.

[65]This duty was certainly given to secretaries of the Royal Society of London, the Royal Edinburgh Society, and the Manchester Literary and Philosophical Society. Hall, p. 139; Campbell and Smellie, p. 54.; Kargon, p. 75.

[66]Hall, p. 136.

[67]Michael Foster; quoted in Hall, p. 136.

Table 2A: Mathematical† Officers of British Scientific Societies, 1800-1900

Society	President		Gen. Secty.		For. Secty.		Treas.		Trustee	
	in # ‡	in %*	in #	in %	in #	in %	in #	in %	in #	in %
R. S. Lond.	3	18%	5	26%	1	8%	3	21%		
R. S. Edin.	2	17%	2	34%	-	-	0	0%	-	-
R. Irish Ac.	8	44%	-	-	-	-	-	-	-	
R. Astro. S.	10	30%	10	30%	3	23%	0	0%	-	-
BAAS	15	21%	4	10%	-	-	1	17%	5	42%

† Here, "mathematical" means that the officer, had, at some time in his life, published a mathematical paper or taught mathematics.

‡ If an officer served more than once in the same post, that service is only counted once. For example, J.F.W. Herschel served four distinct tenures as President of the Royal Astronomical Society; however, he is only counted as one mathematical President of this society.

* Percentages are rounded to the nearest 1.0%.

§ Blank areas mean that either the office did not exist for the society (for example, only the BAAS had Trustees), or no list of officers was found for that office.

These figures may be underestimates, because if no definitive biographical information was found for an officer, he was counted here as non-mathematical. In particular, the mathematical activity of six officers of the Royal Society of Edinburgh and four officers of the Royal Astronomical Society could not be determined.

in the *Lady's and Gentleman's Diary* in 1844.[68] After establishing his reputation as a mathematician, Kirkman focused once again on a prize question. In 1861, the Paris Académie des Sciences announced a Grand Prix de Mathématiques to be awarded to the mathematician who "perfects in some important point the geometrical theory of polyhedra,"[69] and this prompted Kirkman to consolidate his research in this area. While he ultimately never submitted his work for consideration, he did present it to the Royal Society of London.[70] In this 21-section article, "On the Theory of

[68] N.L. Biggs, "T.P. Kirkman, Mathematician," *Bulletin of the London Mathematical Society* 13 (1981): pp. 97-120 on pp. 97-98.

[69] Grand Prix de Mathématique question for 1861; quoted in *ibid.*, p. 105: "Perfectionner en quelque point important la théorie géométrique des polyèdres."

[70] Kirkman had earlier submitted an entry for the 1860 Grand Prix question concerning groups of substitutions. While the prize committee recognized innovations in his, and especially the memoirs of the other two contestants, Camille Jordan and Émile Mathieu, they believed that none of the submissions warranted the prize (Biggs, pp. 106-107). Kirkman wrote to Stokes that "I am so annoyed at the manner in which the Académie had their competition in refusing to acknowledge any

Polyedra,"[71] Kirkman tackled the enumeration and classification of polyhedra.

The referees assigned to Kirkman's massive treatise handled their task in a variety of ways. Thomas Archer Hirst declined to report on the memoir, citing a lack of expertise in the area as well as a lack of time.[72] William Spottiswoode reported that, "although I have not really mastered its contents, I have seen enough of it to recommend it for publication in the Philosophical Transactions."[73] Unlike Spottiswoode, Arthur Cayley was not satisfied with the paper and criticized the quality of its contents:

> It is very probable that Mr. Kirkman's paper on Polyhedra contains results of great value and that he may have effected as he claims to have done the solution of the problem of the classification and enumeration of Polyhedra. But it appears to me on the first page (which is all that I have read) of the memoir that the author has not taken sufficient pains to present his results in a clear and intelligible form and that the memoir ought really to be rewritten... it would be a mere waste of time to attempt reading a paper characterised by such a want of precision of expression.[74]

Clearly unhappy with the latter referee's opinion, Kirkman argued his case to the Royal Society Secretary, Stokes. He declared that "I have written all that I intend to rewrite"[75] and that except for one small detail,

---

of their results, and so suspicious of their fairness to the Foreigner, that I have determined ... not to send it [his memoir on polyhedra] to Paris, but to present it to the Royal Society." Thomas P. Kirkman to Stokes, 13 April 1861, Stokes Papers, Cambridge University Library, Add 7656, RS242.

[71] Alexander MacFarlane related that Kirkman preferred to write "polyedron" instead of "polyhedron," because the spelling of "periodic" is not "perihodic." Alexander MacFarlane, *Lectures on Ten British Mathematicians of the Nineteenth Century* (New York: John Wiley & Sons, 1916), p. 126.

[72] Referee's Report, Thomas Archer Hirst, 23 June 1861, Royal Society Archives, London, R.R.4.147.

[73] Referee's Report, William Spottiswoode to Stokes, 4 July 1861, Royal Society Archives, London, R.R.4.148.

[74] Referee's Report, Arthur Cayley, 1861 [day and month unknown], Royal Society Archives, London, R.R.4.150.

[75] Thomas P. Kirkman to Stokes, 14 Dec. 1861, Stokes Papers, Cambridge University Library, Add 7656, RS284.

> I have not been able to discover the slightest value in the remarks of your Referee... In all the work I have not been able to find an example of the carelessness of composition with which he charges me; and I consider it to be a simple piece of incivility only excusable on the ground of his not understanding the subject, when he says that I never used certain definitions... 'for no other purpose than to save the author the trouble of defining &c.' There is not the least uncertainty that my work should be printed by the R.S. And indeed, if it was printed, I suspect that no few men in the world will read it.[76]

A week later, Kirkman again engaged Stokes with details of his disagreement with the referee. He clarified that the object of his quarrel was neither the Royal Society nor its Council and that he would not want the referee,

> wherever he may be, to know what I say of his criticisms. I am perfectly unconscious of having done or said anything that should have led him to treat me so harshly: and it is possible that the newness & difficulty of the subject may have so rebuffed him... But he has certainly failed completely to justify his own severity - and has not alluded to anything *out of the first page.*[77]

Cayley evaluated Kirkman's revisions to the paper but still considered "the labor of going thro' it ... far more than I am able to undertake."[78] However, he proposed the publication of the first two sections (which still occupied 40 quarto pages) and noted that "to save his rights of priority the author would probably wish and there would be no objection that the Introduction and Table of Contents of the whole memoir should be published with the first two sections."[79] The Royal Society published Kirkman's work in the manner Cayley suggested.[80] In the published version's introduction, Kirkman pointed out that besides the two sections "here presented to the

[76] *Ibid.*

[77] Thomas P. Kirkman to Stokes, 21 Dec. 1861, Stokes Papers, Cambridge University Library, Add 7656, RS287. Kirkman's emphasis.

[78] Referee's Report, Arthur Cayley, 17 Feb 1862, Royal Society Archives, London, R.R.4.150.

[79] *Ibid.*

[80] Thomas P. Kirkman, "On the Theory of the Polyhedra," *Philosophical Transactions of the Royal Society of London* 152 (1862): 121-165.

public... [m]uch remains of the entire work, which is, however, completely written, and in the possession of the Royal Society."[81] Besides publishing some of the memoir's tables in its *Proceedings*,[82] the Royal Society never published these remaining sections, and Kirkman never again published his work in Royal Society journals. He did recognize the role of Stokes in the affair, writing that "the trouble you have had with me gives me a very lovely idea of patience and fortitude of a Sec^y of the Royal Society. You have no sinecure evidently."[83]

Throughout the nineteenth century, British mathematicians served in a variety of administrative offices of general scientific societies (see Table 2A). Their election to these positions represented, as in the case of William Thomson, recognition of an extraordinary scientific career. As the case of Stokes illustrates, however, a society office could mean much more than an honorific title. As officers, British mathematicians had opportunities and responsibilities to shape the policies of their societies. In particular, as secretary-editors, they helped define the level, amount, and placement of mathematics in a venue that also had to accommodate publications from non-mathematical fields of science. By 1820, British mathematicians desiring an active membership in a scientific society could turn to one devoted to only one scientific area in which mathematics played an integral role: astronomy.

[81] *Ibid.*, p. 122.

[82] Thomas P. Kirkman, "Applications of the Theory of the Polyedra to the Enumeration and Registration of Results" *Proceedings of the Royal Society of London* 12 (1862-1863): 341-380.

[83] Thomas P. Kirkman to Stokes, 2 Jan. 1862, Stokes Papers, Cambridge University Library, Add 7656, RS291.

The Royal Astronomical Society Widens the Mathematical Publication Venue

New societies devoted to specialized disciplines emerged to fill the need for other publication forums besides those of general scientific societies. The foundation of these new specialized societies was not entirely painless. In particular, Banks formed a major obstacle to their formation in the opening decades of the nineteenth century. While he initially supported the establishment of the Linnean Society, a society founded in 1788 and devoted to botany and zoology, he eventually perceived specialized societies as a threat: "Banks felt that they would dismantle the parent body by siphoning off talent and money, and he feared that the *Philosophical Transactions* would suffer irrevocably if men were to submit their findings to the new societies instead of the Royal Society."[84] The establishment of a London-based astronomical society in 1820 did not escape Banks's wrath. After the Royal Society President persuaded his friend, the Duke of Somerset, to refuse the inaugural presidency of the new society, Francis Baily complained to his friend, John Herschel, that

> it surely cannot be maintained for a moment, that, because a person is a member of the Royal Society, he is precluded from joining any other Society which has Science for its object: and after the fruitless and more violent attempt, which Sir Joseph made against the Geological Society & the Royal Institution (and which only tended to unite more firmly the original members) I wonder that he should again endeavour to oppose the progress of science in this particular instance.[85]

Although Baily worried about the Royal Society President's control over the Astronomical Society, Banks's death five months after the new society's founding left it free to develop.

[84]Gleason, p. 39.
[85]Francis Baily to J.F.W. Herschel, 11 Mar. 1820; quoted in Gleason, p. 55.

Once founded, the Royal Astronomical Society (RAS) had to establish the procedures by which it would select and publish papers in its *Memoirs*. Initially, after a paper was read to the society, a Secretary presented the work in abstracted form to the Council. The Council then voted to refer the paper to a committee of the Chair's nomination. After making any alterations suggested by this committee, the author resubmitted the paper to the Council, whose vote decided if it would be published. In 1825, revised regulations relieved the secretaries from making abstracts and instead sent the paper directly to appointed referees after it was read. If these referees and the Chair of the Council saw fit, the paper could bypass the Council and proceed to the *Memoirs*; otherwise, the Council voted on its future.[86]

Soon, the slowness with which the *Memoirs* appeared induced the RAS to create a new instrument of publication. Since its inception, the Society had received notice in the independent scientific journal, the *Philosophical Magazine*.[87] In 1827, the Society arranged for the magazine to print separate copies of astronomical news for the use of the fellows. By its third volume in 1834, these *Monthly Notices of the Royal Astronomical Society* had become a Society, instead of a private, venture.[88]

Like the *Proceedings of the Royal Society of London*, the *Monthly Notices* gained in importance, and soon short papers were directed to its pages rather than to those of the *Memoirs*.[89] In 1847, the reputation of the *Monthly Notices* further solidified:

[86]Herbert H. Turner, "The Decade 1820-1830," in *The History of the Royal Astronomical Society 1820-1920*, ed. John L.E. Dreyer and Herbert H. Turner (London: Royal Astronomical Society, 1923; reprint ed., Oxford: Blackwell Scientific Publications, 1987), pp. 1-50 on pp. 36-37.

[87]For more on the *Philosophical Journal*, see chapter 3.

[88]Turner, pp. 40-41. A second publishing company, Priestly & Weale, controlled the journal before the Society took over. *Ibid.*, p. 40.

[89]John L.E. Dreyer, "The Decade 1830-1840," in *The History of the Royal Astronomical Society*

"[t]heir contents were to be considered a sustantive record of the proceedings of the Society, a portion of its *Memoirs*; in it also were printed such observations or papers as had an immediate interest or were in a transition state of reduction."[90] In the midst of these changes, the Society Secretary and editor of the journal, Richard Sheepshanks, explained the balance between bureaucracy and autonomy that he thought was needed in editing the *Monthly Notices*:

> If the Monthly Notices are to have any value, they must appear as early as possible & in many instances in the words of the author. Any committee to regulate this operation would bring all to a standstill, a danger which regulators sometimes forget.... On the other hand it is very necessary that the Council should be fully acquainted with all proceedings and not be implicated by the acts of one ... officer, over whom they have no immediate control.[91]

In fact, Sheepshanks' editorship leaned more towards autonomy than bureaucracy: "[t]he compression and arrangement of the matter [in the *Monthly Notices*] was left in great degree to his discretion."[92]

Unlike other nineteenth-century British scientific societies, the RAS did not place the editorship of its journals exclusively in its secretaries. For example, Arthur Cayley edited both of the Society journals for 20 years despite never having served as a Secretary. However, after Cayley resigned as editor in 1881, the Society formally decided to place its editorial duties in the hands of its secretaries.[93] One Secretary

1820-1920, pp. 50-81 on p. 80.

[90]Ralph Allen Sampson, "The Decade 1840-1850," in *The History of the Royal Astronomical Society 1820-1920*, pp. 82-109 on p. 84.

[91]Richard Sheepshanks, "Mr. Sheepshanks' Report to this Council upon the Monthly Notices May 14 1847," Royal Astronomical Society Papers, 45, folder 2.

[92]Sampson, p. 84.

[93]John L.E. Dreyer, "1880-1920," in *The History of the Royal Astronomical Society 1820-1920*, pp.212-253 on p. 239. For their work, these secretaries were paid £50 per year. *Ibid.*

at the time of this resolution, Glaisher, added these new duties to his editorship of the independent mathematical journal, the *Messenger of Mathematics*.[94]

As the examples of Cayley and Glaisher show, mathematicians were active in the RAS both before and after the creation of British mathematical societies. In fact, at least 30% of the Society's nineteenth-century presidents and secretaries taught or published mathematics (see Table 2A). Included among this group were Charles Babbage (Secretary, 1820-1824), Olinthus Gregory (Secretary, 1824-1828), Augustus De Morgan (Secretary, 1831-1839; 1847-1855), Cayley (President, 1872-1874), and Glaisher (Secretary, 1877-1884; President 1886-1888).

In its early days, the RAS represented a new outlet of society activity for reform-minded mathematicians, such as Babbage and Herschel, who were unhappy with the state of the Royal Society. Even after the Royal Society had mended many of its contentious ways, these mathematicians maintained an interest in the RAS. As a field built on a foundation of applied mathematics, astronomy was specialized yet inclusive of mathematics.[95] Cayley and Glaisher, primarily recognized for their research in pure mathematics, made valuable contributions to the publications of the RAS as both editors and authors.[96] The RAS made room for British mathematicians,

[94]For more on the *Messenger of Mathematics*, see chapter 4.

[95]For more on the study of astronomy in nineteenth-century Britain, see chapter 7.

[96]For a significant series of contributions made by Cayley in response to the contribution regarding the motion of the moon, see chapter 6. Glaisher wrote several papers about logarithmic tables and the method of least squares. For example, James Glaisher, "On the Law of Facility of Errors of Observations and on the Method of Least Squares," *Monthly Notices of the Royal Astronomical Society* 32 (1872): 241-242 and *Memoirs of the Royal Astronomical Society* 39 (1872): 75-124; "On the Progress to Accuracy of Logarithmic Tables," *Monthly Notices of the Royal Astronomical Society* 33 (1873): 330-345; "On Logarithmic Tables," *Monthly Notices of the Royal Astronomical Society* 33 (1873): 440-450; "On the Solution of the Equations in the Method of Least Squares," *Monthly Notices of the Royal Astronomical Society* 34 (1874): 311-314; "On the Method of Least Squares,"

who gladly accepted the opportunity to participate in the society. A decade after the foundation of the RAS, some of the same mathematicians active in its creation also turned their energies towards the British Association for the Advancement of Science, a hybrid organization that provided a forum for both general and specialized science.

Reaction to the *Status Quo*: The Foundation of the British Association for the Advancement of Science and its *Reports*

Amid an environment of scientific and political reform, the British Association for the Advancement of Science emerged as a scientific society with aims and procedures distinct from those of the scientific societies discussed above. Founded in 1831, the BAAS distinguished itself by migratory annual meetings in metropolitan, academic, industrial, provincial, and colonial centers, as well as by offering opportunities for participation at different levels of scientific skill and social standing.[97]

From the outset, the BAAS considered the production and diffusion of scientific papers as a measure of credibility and a valuable product of their meetings. To ensure that it would be led by "those who appear to have been actually employed in working for science," the Association required that its governing "General Committee shall consist of *all Members present at a* [BAAS] *Meeting who have contributed a paper to any Philosophical Society, which paper has been printed by its order or with its concurrence.*"[98] While the BAAS gave administrative power to scientists who had published papers, it also actively solicited papers through its disciplinary sub-committees: "the

Monthly Notices of the Royal Astronomical Society 40(1880): 600-614, 41 (1880): 18-83.

[97]Morrell and Thackray, pp. 108, 135.

[98]William Vernon Harcourt, "Objects and Plan of the Association," *Report of the British Association for the Advancement of Science* (1831-1832): 21-41 on p. 35. Harcourt's emphasis.

Sub-Committees should *select the points in each science which most call for inquiry, and endeavor... to engage competent persons to investigate them;... they should attend especially to the important object of obtaining Reports in which confidence may be placed, on the recent progress, the actual state, and the deficiences of every department of science.*"[99]

British mathematicians promptly answered this call by the Association for reports on the state of their science. In 1833, only a year after the first such publications appeared in the *BAAS Report*, the Cambridge mathematician, George Peacock, produced his "Report on the Recent Progress and Present State of Certain Branches of Analysis."[100] Together with his 1830 *Treatise on Algebra*, Peacock's "Report" represented one of the first steps in the British movement to solidify the foundations of algebra.[101] Taking for his mission "nothing less than the construction of a deductive science of symbolical algebra, with first principles sufficient to justify inclusion of the negatives and imaginaries,"[102] Peacock reacted to the late eighteenth- and early nineteenth-century criticisms of Francis Maseres and William Frend. These two Cambridge graduates advocated an algebra stripped of negatives and imaginaries, notions that to them lacked concreteness, "a parcel of algebraick quanities, of which our understandings cannot form any idea."[103]

---

[99] *Ibid.*, p. 36. Harcourt's emphasis.

[100] George Peacock, "Report on the Recent Progress and Present State of Certain Branches of Analysis," *BAAS Report* (1833): 185-352.

[101] Joan L. Richards, "The Art and Science of British Algebra: A Study in the Perception of Mathematical Truth," *Historia Mathematica* 7 (1980): 343-365 on p. 346. George Peacock, *Treatise on Algebra* (Cambridge: J. and J.J. Deighton, 1830).

[102] Helena M. Pycior, "George Peacock and the British Origins of Symbolical Algebra," *Historia Mathematica* 8 (1981): 23-45 on p. 24.

[103] Francis Maseres, quoted in Helena M. Pycior, "Internalism, Externalism, and Beyond: 19th-

In the "Report," Peacock presented an innovative but limited curative to the algebraic ills perceived by these critics. Negatives and imaginaries posed problems in arithmetic, but not in "symbolical algebra." This algebra was related to arithmetic through a process that was not "an ascent from particulars to generals... but one which is essentially arbitrary;"[104] it was, however, "restricted with a specific view to its operations and their results admitting of such interpretations as may make its applications most generally useful."[105] Peacock required agreement at any intersection of arithmetic and his algebra.[106] Peacock's "symbolical algebra" presented to the BAAS, although not free of interpretation, directed future British investigators' attention to "the laws of operation. It was this aspect of his work, upon which Augustus De Morgan, Duncan F. Gregory, George Boole, and other British pioneers of mathematics constructed modern abstract algebra during the second third of the 19th century."[107]

In addition to Peacock's landmark contribution to pure mathematics, the BAAS also received valuable reports from young, talented authors on applied mathematical topics. In 1833, three years before his election as Plumian Professor of Astronomy and Experimental Philosophy in Cambridge, James Challis, presented a "Report on the present State of the Analytical Theory of Hydrostatics and Hydrodynamics." The next year, William Whewell, who would soon become the Master of Trinity College,

Century British Algebra," *Historia Mathematica* 11 (1984): 424-441 on 429-430.

[104]Peacock, "Report," p. 194, quoted in Richards, p. 347.

[105]*Ibid.*

[106]Richards, p. 348.

[107]Pycior, "George Peacock," p. 36.

Cambridge, gave a "Report on the Recent Progress and Present Condition of the Mathematical Theories of Electricity, Magnetism, and Heat." Finally, as a young Cambridge Fellow, Stokes contributed the 1846 "Report on Recent Researches in Hydrodynamics; this publication is cited as a major factor in the establishment of his scientific reputation.[108]

The BAAS continued receiving valuable mathematical reports during the second half of the nineteenth century. Arthur Cayley, now known primarily for his work in pure mathematics, reported in 1857 "On the Progress of Theoretical Dynamics." The Oxford mathematician, Henry J.S. Smith, through the first half of the 1860s, codified an area of mathematics neglected by British mathematicians in his series of "Report[s] on the Theory of Numbers."[109] In his 1860 presidential address to the Mathematics and Physical Sciences Section of the BAAS, Oxford's Sedleian Professor of Natural Philosophy, Bartholomew Price, claimed that

> we have a debt to pay, due by the cultivators of these branches of science, to those who have lately contributed reports on particular parts of our science to the British Association; — to Mr. Cayley for his report on the present state of Theoretical Dynamics, and to Mr. Smith for the first part of his report on the Theory of Numbers... we know thereby all that has been done up to a certain point, and in our subsequent investigations our commencement starts from the close of other men's labours. We are hereby prevented from travelling over other men's ground... Vast and

[108] Charles C. Gillispie, ed. *Dictionary of Scientific Biography*, 16 vols. and 2 supps (New York: Charles Scribner's Sons, 1970-1990), s.v. "Stokes, George Gabriel;" James Challis, "Report on the Present State of the Analytical Theory of Hydrostatics and Hydrodynamics," *BAAS Report* (1833): 131-152; William Whewell, "Report on the Recent Progress and Present Condition of the Mathematical Theories of Electricity, Magnetism, and Heat," *BAAS Report* (1835): 1-34; George Gabriel Stokes, "Report on Recent Researches in Hydrodynamics," *BAAS Report* (1846): 1-19.

[109] Arthur Cayley, "On the Progress of Theoretical Dynamics," *BAAS Report* (1857): 1-42; H[enry] J. Stephen Smith, "Report on the Theory of Numbers," *BAAS Report* 28 (1859): 228-267; 29 (1860): 120-172; 30 (1861): 292-340; 31 (1862): 503-526; 32 (1863): 768-786; 34 (1865): 322-374. For more on Smith's reports, see chapter 7.

> various are the benefits of our Association; but I am inclined to consider as one of the greatest, the series of valuable reports which our published volumes contain... While we lament the loss of Dr. Peacock and others, to whom we owe the very able reports contained in the early volumes of our proceedings, we are proud to have worthy successors in our present talented contributors.[110]

The mathematical reports of the BAAS helped British mathematicians wade through the ever increasing flow of mathematical results.

The *BAAS Report* also offered a soapbox for British scientists by publishing the presidential addresses. Initially, the BAAS President chosen each year would be selected as a representative from the meeting's host city or, like the Royal Society presidents of the early nineteenth century, as a consequence of his social standing.[111] The presidency soon developed into "one of the highest honours which science could bestow upon its cultivators; and as a corollary, it also became an accepted view that the locality of a meeting (unless in exceptional circumstances) should welcome the president as a distinguished visitor, rather than that he should welcome the Association in his own place," and the presidential address became "the principal public scientific pronouncement of the year."[112] For over one-fifth of the nineteenth-century meetings of the BAAS, British mathematicians served in this office (see Table 2A). Their addresses could reflect a wide spectrum of mathematical issues, or, in the case of Arthur Cayley, a wide spectrum of mathematics.

Upon his election as BAAS President in 1883, Cayley decided to give an overview of the interests, questions, and directions of actively researching mathematicians. The

[110]Bartholomew Price, "Address," *BAAS Report* (1860): 1-3 on p. 2.
[111]Howarth, p. 107.
[112]*Ibid.*, pp. 107-108.

prospect of an address on pure mathematics, rather than popular science, failed to thrill a reporter for the *Times*: "[o]f the president of the year, Professor Cayley, even Senior Wranglers [the highest ranked mathematical honors students at Cambridge] speak with bated breath and hopeless wonder. Only Professor Sylvester is believed to come anything near to fathomming the depth of Professor Cayley's mathematical attainments; it has therefore, been feared that the Southport presidential address would not be of a character to appeal to a popular audience."[113] Cayley delivered with unmatched "erudition and authority" an address covering a wide expanse of mathematics.[114] The breadth and thoroughness of the address represented a major accomplishment in light of the rapid development and specialization of mathematics, but even "the kindest reviews judge that such an Address was not suitable to a typical British Association audience who were essentially 'wonder loving' but not scientific."[115]

Besides presidential addresses and reports, the *BAAS Report* also gave accounts of the results presented in its sectional meetings. The sections were organized by discipline and provided opportunities for scientists in each discipline to establish a sense of unity and identity.[116] In contrast to the Royal Societies of London or Edinburgh where papers were read without discussion, "the hallmarks of the [BAAS] Sections were informal participation, general discussion and evaluation within a group

[113] *The Times*, 1 Sept. 1883, quoted in Tony Crilly, *Arthur Cayley, Mathematician Laureate of the Victorian Age*, preprint, chapter 15, p. 10.
[114] *Ibid.*, chapter 15, p. 20.
[115] *Ibid.*, chapter 15, pp. 21-22.
[116] Morrell and Thackray, p. 451.

of intellectual peers."[117]

In the underlying hierarchy of the sections, the mathematical and physical sciences Section A was first in reputation as well as alphabetically: "[t]he mathematical and physical sciences enjoyed the commanding heights of the Association's intellectual economy. While the meetings of Section A were more arcane and less crowded than those devoted to geology or statistics, the interests at stake were closer to the heart of the Association's affairs. Discussion was correspondingly intense."[118] The high position of Section A can be seen in the distribution of BAAS grants during the nineteenth century: almost half of the funds were directed to mathematics and physical sciences; with almost one-fifth of the funding, botany and zoology came in at a distant second.[119] The mathematicians of Section A received funds for the construction of mathematical tables of time-intensive calculations for elliptic functions, factorizations, invariants, and integrals.[120]

While the products of BAAS grants were often published in the Association's *Reports*, they also provided material for other scientific journals. For example, Sylvester published his tables on fundamental invariants, funded by the BAAS, in his newly

[117] *Ibid.*, p. 460.

[118] *Ibid.*, p. 466.

[119] O.J.R. Howarth, *The British Association for the Advancement of Science: A Retrospect, 1831-1931* (London: BAAS, 1931), pp. 266-292. In Howarth's listing, some of these grants extended into the twentieth century; these grants were included in the nineteenth-century calculations above. Geology, Anthropology, Engineering, and Chemistry came in at as the next best funded sections, with about 17%, 15%, 9%, and 8% of the grants, respectively. The BAAS established monetary grants as a method to guide and support science with the considerable funds it amassed through membership dues. The research resulting from these grants was often published as lengthy articles in the *BAAS Report*. See Morrell and Thackray, pp. 312-324.

[120] The years and amounts (rounded to the nearest £) of these grants were: elliptic functions, 1874-1877, £500; factor tables, 1878-1879, £250; fundamental invariants, 1879-1882, £121; integrals, 1896-99, 1896-99, £40. Howarth also lists grants for tables in number theory, 1885, £100; Pellian equation, 1890-1892, £25; and "certain functions," 1893-1900, £130. *Ibid.*, p. 208.

established *American Journal of Mathematics.*[121] Products of the BAAS often overflowed into other British scientific journals. William Thomson, BAAS President in 1871, remarked in 1888 that "[n]o one not following the course of scientific progress, generally or in some particular department, can fully understand how much of practical impulse is owing to the British Association for the contributions made in the course of the year to the scientific societies and magazines, in which achieved results of scientific investigation are recorded and published."[122]

With such an abundance of scientific material and correspondingly high printing costs,[123] the *BAAS Report* usually limited the account of its sectional proceedings to short abstracts. The reader, however, was often pointed towards the journals where the papers were printed *in extenso*. These sectional proceedings then informed mathematicians who could not attend the meeting and served as a bibliographic resource for the papers presented there.

Section A allowed mathematicians to discuss their research in a more specialized setting than that of the other general scientific societies. This capability was especially important since Britain lacked a major mathematical society until 1865. The 1860 remarks of Section A President, Bartholomew Price, however, indicated that the higher level of specialization of a society devoted solely to mathematics was long overdue: "[t]o many of the usual attendants on this Section, these [mathematical] and kindred subjects may be dry and uninteresting. Well, if they are so to any of

[121] For more on these tables of invariants, see chapter 7.
[122] William Thomson, quoted in Howarth, p. 256.
[123] *Ibid.*, pp. 257-258.

you, I must beg you bear with us for a short time; these things have a deep and significant meaning; and be assured too that they are not uninteresting to all; to many they give the purest pleasure; and I must ask you not to grudge them *that* during the few papers on higher mathematics which we shall probably have."[124]

Without a major society of their own, British mathematicians probably envied the scientists of the BAAS Section F. This section, devoted to statistics, served as the catalyst for a new specialized society. When Adolphe Quetelet, the Belgian delegate to the Association's 1833 meeting, found no proper forum in which to read his statistical paper, BAAS members arranged a special meeting. This gathering spawned the foundation of Section F of the Association and, a year later, the Statistical Society of London.[125]

As the case of statistics shows, the BAAS changed the organization of nineteenth-century British science. Like a scientific Olympic games, it left an indelible mark on each of its host cities: "[w]here the British Association trod, museums were rebuilt, zoos were restocked and gardens grew, surveys blossomed and worthies billowed. The business of scientific communication, no longer restricted to the printed page, personal letter, or private lecture, was transformed into a pluralistic, public activity, and in the process transformed public expectations of British science."[126] The BAAS did employ the communication tool of "printed page" by issuing its annual *Report.*

[124]Bartholomew Price, pp. 1-2.

[125]Ian David Hill, "Statistical Society of London-Royal Statistical Society: The First 100 Years: 1834-1934," *Journal of the Royal Statistical Society, Series A* 147 (1984): 130-139 on pp. 130-131.

[126]Roy MacLeod, "Retrospect: The British Association and its Historians," in Roy MacLeod and Peter Collins, ed., *The Parliament of Science: The British Association for the Advancement of Science, 1831-1981* (Middlesex, England: Science Reviews Ltd., 1981): 1-16 on p. 12.

British mathematicians reaped the benefits of the BAAS and its periodical as a dual forum from which to address each other and the rest of the scientific world.

The Place of Mathematical Papers in Scientific Society Journals

So far this chapter has looked at the influence of individual British mathematicians in scientific societies through their work as editors, referees, and officers. What was the place of the British mathematical publication community as a whole within these societies? We can approach an answer to this question by looking at the proportion of pages mathematics occupied in these societies' journals (see Table 2B).[127]

Table 2B: Percentage of Mathematical Pages in Scientific Society Journals†

Journal	1800-1836	1837-1867	1868-1900	Total # of Pages♮
Phil. Trans. RS London	13.5%	15.2%	32.1%	63,292
Proc. R.S. London	11.6%	14.7%	9.0%	36,153
Trans. R.S. Edinburgh	13.1%	23.7%	12.1%	20,855
Trans. R. Irish Acad.	36.8%	29.7%	26.0%	10,415
[Mem. &] Proc. Manchester‡	—	12.4%	4.1%	9,349
Mem. Manchester	14.2%	17.4%	9.3%	9,866
Monthly Not. R. Astro. S.	5.8%	8.5%	6.1%	23,703
Mem. R. Astro. S.	7.7%	15.5%	20.5%	13,835
BAAS Report§	24.3%	5.5%	18.8%	27,886

† These percentages represent the number of pages over the given time period devoted to mathematical subjects out of all the pages in the journal.

‡ This includes pages from the *Proceedings of the Manchester Literary and Philosophical Society*, which existed from 1857 to 1887 and the amalgamated *Memoirs and Proceedings* from 1888 to 1900.

§ This includes only the reports, and not the proceedings of the transactions, of the BAAS.

♮ These page totals have sometimes been estimated when the end page of the volume was not available. Special volumes devoted to non-mathematical topics are not included in the total page count.

[127] In Table 2B, we consider only the primary journals of each society except in the case of the Royal Society of London, the Manchester Literary & Philosophical Society, and the Royal Astronomical Society, whose secondary journals grew to rival or overtake their original journals. The percentages for 1868-1900 are based on the categorizations of the *Jahrbuch über die Fortschritte der Mathematik*, except for the Manchester *Memoirs*, the Royal Astronomical Society *Memoirs*, and the BAAS *Report*, journals that were only sporadically reviewed by the *Jahrbuch*. For more on the *Jahrbuch* categorization and periodization of Table 2B, see chapter 7.

Of these journals, mathematics made its strongest showing in the *Transactions of the Royal Irish Academy* with over one-quarter of the pages for each period. These figures correspond to the high activity of mathematicians in the administration of the Royal Irish Academy.

The Royal Society of London also published a substantial number of pages on mathematics in its *Philosophical Transactions.* The mathematical share of pages in this journal climbed to almost one-third by the last period of Table 2B. This portion was much lower for the first period, which coincided for 20 years with the presidency of Sir Joseph Banks. Interestingly, the representation of mathematics in the *Proceedings of the Royal Society of London* was considerably lower than that of its parent journal for 1868 to 1900. Robert Mortimer Gascoigne calculated that chemistry, however, occupied 18% of the *Proceedings* for the nineteenth century.[128] This underscores the fact that different journals, even those published under the auspices of the same society, accommodated different disciplines at different periods.

In general, mathematics had a noticeable presence in all of the journals of Table 2B. All but two journals increased their mathematical percentages for 1837 to 1867, when British mathematics was still in need of its own societies. One notable exception is the *Report* of the BAAS. The BAAS, as a young society, had actively stocked up on reports on the progress of mathematical fields.[129] Surprisingly, these journals still

[128]Gascoigne, p. 16. Gascoigne did not single out mathematics in his calculations, but found that the mathematically related fields of physics and astronomy occupied 18% and 10%, respectively. Zoology occupied 9%, physiology 6%, meteorology 6%, and other subjects 25%.

[129]Morrell and Thackray calculate that Section A produced 46 percent of the BAAS reports from 1832 to 1834, and 40 percent from 1836 to 1841. Morrell and Thackray, pp. 291-296.

maintained substantial percentages during 1868 to 1900, a period during which three British mathematical societies began to flourish. This fact indicates that the journals of mathematical societies did not replace but instead supplemented those of general scientific societies as publication venues for mathematics. During the nineteenth century, published research in mathematics experienced rapid growth and needed all the room it could find.[130] The authors of this research remained involved in Britain's general scientific societies even as they were founding societies of their own. It is to these specialized societies and their journals that we now turn.

A New Stage of Specialization: The Emergence of British Mathematical Societies

Although British specialized scientific societies blossomed in the second quarter of the nineteenth century, mathematics would not have a major society in Britain until 1865. However, before 1865, mathematical societies had not been totally absent there. For instance, the Spitalfields Mathematical Society, founded in 1717, originally consisted "of working men who after a day's toil sought recreation in the form of intellectual exercise of a non-utilitarian character."[131] In time, the members of the society became more bourgeois and began offering public lectures on a variety of subjects. However, by the 1840s, many of the members had left for the new specialized societies, and, in 1845, the society was absorbed into the Royal Astronomical Society.[132] Other early mathematical societies were much less tenacious than the one

[130] For statistics on the growing number of mathematical articles during the nineteenth century, see chapter 7.

[131] John William Scott Cassels, "The Spitalfields Mathematical Society," *Bulletin of the London Mathematical Society* 11 (1979): 241-258 on p. 242.

[132] *Ibid.*, pp. 245-251.

in Spitalfields. For example, the Analytical Society, established in 1812, produced a volume of *Memoirs* but survived only two years (see chapter 4).[133]

Despite the dissolution of these earlier societies, in 1865, British mathematicians enthusiastically received the London Mathematical Society (LMS). Proposed by Arthur Cowper Ranyard and George Campbell De Morgan, two recent graduates of University College, London, the Society initially had the flavor of a student club.[134] However, after five months, it had doubled its membership; by 1866, it numbered 94 members, with over half unconnected to University College.[135] In a letter asking Sir John Herschel to join the Society, Sylvester wrote that "[t]he Society is making steady progress and includes in its ranks many of the best men of the Universities addicted to Mathematical Studies."[136] While much of the Society's growth can be attributed to the efforts of Sylvester, its second President, and Thomas Archer Hirst, its first Vice-President, "[t]he sharp rise in membership also illustrates the very real need which existed for a mathematical society at this time; such a scheme was clearly

[133]Philip C. Enros, "The Analytical Society (1812-1813): Precursor of the Renewal of Cambridge Mathematics," *Historia Mathematica* 10 (1983): 26-37 on p. 37. Besides these two examples, there were at least seven other British mathematical societies. Organized in the eighteenth century, these were centered at London, Manchester, Lewes, York, Wappin, and Oldham. Danny J. Beckers, " 'Untiring Labour Overcomes All!' The Dutch Mathematical Society in European Perspective," *Historia Mathematica* 28 (2001): 3147 on pp. 40-44.

[134]Adrian C. Rice, Robin J. Wilson, and J. Helen Gardner, "From Student Club to National Society: The Founding of the London Mathematical Society in 1865," *Historia Mathematica* 22 (1995): 402-421 on p. 404. George Campbell De Morgan was the son of Augustus De Morgan, who became the first President of the society. For its first meeting, the London Mathematical Society also had the name of a student club, the University College Mathematical Society. Of its 27 initial members, 26 had University College ties. *Ibid.*, p. 407.

[135]*Ibid.*, pp. 410, 415.

[136]James Joseph Sylvester to John Frederick William Herschel, 5 March 1867; in Karen Hunger Parshall, *James Joseph Sylvester: Life and Work in Letters* (Oxford: Clarendon Press, 1998), p. 131. Herschel did join in November 1867. *Ibid.*

long overdue."[137] Compared to similar mathematical societies abroad, however, the London Mathematical Society was not a latecomer; in fact, it represented one of the first national mathematical societies in America or Europe.[138]

Soon after its inception, the London Mathematical Society began publishing a journal. The *Proceedings of the London Mathematical Society* adopted a careful editorial process. An early and sustained member of the LMS council, James Glaisher, recalled:

> [E]very paper was invariably considered by two referees, who sent in written reports which were read to the Council; and when the reports differed the paper was sent to a third referee. Every paper was balloted for, to decide whether it should be printed... At the Astronomical Society, on the contrary, it was rarely that a paper was refereed, and a verbal report from a single referee was generally accepted.[139]

While the Society spent much energy to ensure the quality of its journal, by November 1873, printing costs threatened to abbreviate the format of the *Proceedings.* A committee formed to investigate the Society's finances recommended "that the referees should be more strict, the exact words being that they should consider with regard to each paper 'the merits of the paper and its fitness for the Transactions considered abstractedly', and 'the possibility of reducing its length or printing it in abstract, without serious detriment to the value of the Transactions'."[140] Lord Rayleigh, a Society member since 1871, rescued its finances in 1874 with a £1000 gift that "enabled

[137] *Ibid.*, p. 411.

[138] Recall chapter 1.

[139] James W. L. Glaisher, "Notes on the Early History of the Society," *Journal of the London Mathematical Society* 1 (1926): 51-64 on p. 60. Recall from above that Glaisher was the Secretary of the Royal Astronomical Society from 1877 to 1884, and from 1881 to the end of his secretaryship, he was the editor of its publications.

[140] *Ibid.*, p. 56.

the Society to carry on efficiently its principal work of the publication of papers."[141]

Throughout the nineteenth century, the details inherent in producing almost all the *Proceedings* fell to one man, Robert Tucker. From 1867 to 1902, Tucker served as one of the Society's secretaries[142] and edited the *Proceedings* from its twelfth number to its 766th.[143] While Tucker could not be classed as high as many fellow members in terms of research,[144] the time and attention that he gave the Society were almost unparalleled.[145] In the course of his duties, Tucker "wrote to members to induce them to read papers when the supply was deficient, as it not infrequently was in early days; he sent the papers to the referees, each accompanied by a letter, and did his best to have both reports ready for the next meeting, writing frequent letters and post cards to dilatory referees; and he copied portions, often of great length, from the reports and sent them to the authors; he also attended to passing the papers through the press, and wrote the accounts of the meetings for publication in the various journals."[146]

An example of the guidance and diplomacy Tucker had to provide to authors comes from the papers of Charles Taylor, Master of St. John's College, Cambridge. In response to work Taylor had submitted to the Mathematical Society, Tucker wrote that, "I am directed by the Council to return you your 'Orthoptic' Notes with thanks

[141] *Ibid.*, p. 57.
[142] The other secretaryship was filled for almost as long by Morgan Jenkins. Jenkins accepted the position late in 1865 and retired only in 1894. Augustus Edward Hough Love took Jenkins' place for the rest of the nineteenth century. *Ibid.*, p. 58.
[143] Adrian C. Rice and Robin J. Wilson, "From National to International Society: The London Mathematical Society, 1867-1900" *Historia Mathematica* 25 (1998): 185-217 on p. 204.
[144] Glaisher, p. 59.
[145] Tucker graduated as the 35th Wrangler from Cambridge in 1855, then worked as the Mathematics Master at University College School from 1865 to 1899. Rice, Wilson, and Gardner, p. 420.
[146] Glaisher, p. 58.

& to say that when you have leisure to write out a paper on the same lines they will be happy to receive it & to submit it to the referees in the usual way."[147] To this carefully worded rejection, Taylor responded,

> My paper on Orthoptic Loci was sent in the form of notes because, as I informed you, I had not had time to rewrite it by the day for wh. you desired to have it. May I assume that you communicated this fact to the Society? I am sorry that you did not find the notes 'sufficient,' and should have been glad to have the opportunity of explaining anything wh. you thought insufficiently expressed. I do not wish to have any part of the argument printed until it has been placed in the hands of one or more referees, or returned to me by the Council.[148]

Tucker quickly responded to Taylor and reiterated that "the feeling of the Council was very strong indeed against the 'Notes' being considered as a paper to be submitted to the referees... [and] as I like to close our Volumes by Xmas if possible I shall be glad to have your paper for reference this day I ask for in time for referees to pronounce upon it before the Dec^{r}. meeting."[149] Tucker's indefatigable efforts to uphold the quality and punctuality of the *Proceedings* helped it to become a respected outlet for the publication of research-level mathematics in Britain.

Besides Tucker, other officers worked steadily to help ensure the Society's success. Hirst, H.J.S. Smith, and Cayley accepted the "rather irksome duty"[150] of refereeing papers. Cayley especially supplied papers as well; in fact, at least 78 of his papers are printed in the *Proceedings*, almost nine percent of *all* nineteenth-century *Proceedings* papers.[151] These officers were also active in other scientific societies. In particular, of

[147] Robert Tucker to Charles Taylor, 15 June 1882, Taylor Papers, St. John's College, Cambridge.
[148] Charles Taylor to Robert Tucker, 4 Oct. 1882, Taylor Papers, St. John's College, Cambridge.
[149] Robert Tucker to Charles Taylor, 5 Oct. 1882, Taylor Papers, St. John's College, Cambridge.
[150] Glaisher, p. 63.
[151] Rice and Wilson, p. 205. For the whole nineteenth century, the Society published 914 papers. *Ibid.*

the 18 London Mathematical Society presidents, eight served as President, Secretary, or Treasurer of the Royal Society of London, Royal Society of Edinburgh, Royal Astronomical Society, or the BAAS. Despite his varied society activity, one member of this active group, Hirst, declared that the London Mathematical Society "has been my favourite Society, – the one in which I have taken the greatest interest."[152]

While Hirst's favorite society was devoted to the progress of mathematical research, it failed to be active in mathematical pedagogy.[153] Hirst, however, was interested in both the research and educational realms of mathematics and served as the first President of the Association for the Improvement of Geometrical Teaching (AIGT) in 1871, a year before he served as the fifth President of the LMS.[154]

The new Association, whose goals were declared in its name, took as its first task the creation of a school syllabus of plane geometry that departed from the traditional course of Euclid. In 1868, James Maurice Wilson, senior Mathematical Master at Rugby, complained that "there are scores of schools were boys learn and say their Euclid like declensions."[155] In order to improve this educational situation, Wilson wrote a textbook on geometry, which diverged from the restrictive structure of Euclid's propositions. Wilson discussed his textbook reform and views on Euclid at a meeting

---

[152]Thomas Archer Hirst; quoted in Rice and Wilson, p. 205.

[153]Rice and Wilson, p. 194.

[154]J. Helen Gardner and Robin J. Wilson, "Thomas Archer Hirst – Mathematician Xtravagant: VI. Years of Decline," *American Mathematical Monthly* 100 (1993): 907-915 on p. 910. London Mathematical Society presidents Olaus Henrici and William Spottiswoode also worked actively in the AIGT. Joan L. Richards, *Mathematical Visions: The Pursuit of Geometry in Victorian England* (Boston: Academic Press, 1988), p. 175. Robert Tucker, long-time LMS Secretary, helped found the AIGT and remained active. Rice and Wilson, p. 194.

[155]James Maurice Wilson, quoted in Michael H. Price, *Mathematics for the Multitude* (Leicester: The Mathematical Association, 1994), p. 22.

of the LMS in 1868 but, in his words, "was well 'heckled.'"[156] After this meeting, the LMS disengaged itself from issues in teaching geometry; this instance, furthermore, "seems to have set an important precedent for the LMS of non-involvement in mathematics education and of exclusive concern for the advancement of the subject."[157]

The BAAS also expressed an initial interest in these educational issues. The Section A President for 1869, Sylvester, piqued the interest of the Association in his address when he admitted that "I should rejoice to see... Euclid honourably shelved or buried 'deeper than did ever plummet sound' out of the schoolboy's reach."[158] Knowing, however, that not all the members of his audience shared his opinion, Sylvester continued, "[t]he early study of Euclid made me a hater of geometry, which I hope may plead my excuse if I have shocked the opinions of any in this room (and I know there are some who rank Euclid as second in sacredness to the Bible alone, and as one of the advanced outposts of the British Constitution) by the tone in which I have previously allude[d] to it as a school-book."[159]

In the same year as Sylvester's address, the BAAS organized a committee to consider geometrical instruction. As the superannuated Wilson recalled in 1921, "The names of the members of that Committee were Sylvester and Cayley, H.J.S. Smith and Price, Kelland and Fuller, Salmon and Townsend, Hirst, Spottiswoode and Clifford. Was there ever such a cluster of stars on any Committee? Whether

[156] James M. Wilson, "The Early History of the Association," *Mathematical Gazette* 10 (1921): 239-246 on p. 241.
[157] Michael Price, p. 23.
[158] James Joseph Sylvester, quoted in Michael Price, p. 23.
[159] *Ibid.*

that Committee ever met or reported I do not know. It certainly did not produce a syllabus. I think I should not have forgotten had it ever reported."[160] The committee did, in fact, issue a report, but only after four years of decisive deliberations.[161]

In the absence of interest, in the case of the LMS, or action, in the case of the BAAS, the AIGT began in 1871, 20 years prior to the creation of any other association devoted to the teaching of a secondary school subject.[162] With the exception of Hirst and Oxford Fellow, Wallis Hay Laverty, the AIGT began "as a ginger group of schoolmasters."[163] Their first goal, the creation of a geometry syllabus, proved difficult to attain; after much effort, their syllabus was finally published in two parts in 1873 and 1875.[164] Since it was a compromise, "[i]n the end it appears that the finished syllabus really pleased no one... Although the AIGT continued to meet, and published annual reports through 1893, it did not succeed in creating revolutionary changes in geometrical education."[165] Considering the formidable foes of these reforms, the limited success of the AIGT in this arena is not surprising. Influential Cambridge mathematicians, including Issac Todhunter and Cayley, took a conservative stance on geometrical education.[166] The Oxford mathematician, Charles Dodgson, better known as Lewis Carroll, mocked the AIGT by dubbing it the "Association for the

[160]Wilson, p. 242.
[161]Michael Price, pp. 26, 28.
[162]The Modern Language Association, the next such group, was founded in 1892. *Ibid.*, p. 26.
[163]*Ibid.*, p. 26.
[164]The BAAS committee on geometrical teaching pronounced the 1873 syllabus "decidedly good so far as it goes" and officially endorsed the 1875 final version. *Ibid.*
[165]Richards, pp. 173-174. The geometrical reforms sought by the AIGT were finally adopted by most major English universities (and therefore by schools whose students would eventually attend these universities) in 1903. *Ibid.*, p. 198.
[166]Michael Price, pp. 30-31.

Improvement of Things in General."[167]

While not immediately successful in its primary goal, the AIGT did succeed in providing a publication venue for mathematics education through the publication of its *Report.* In 1883, the Association began accepting and publishing papers on a variety of mathematical subjects in order "to cater for both mathematical and educational interests, and thereby to widen the AIGT's appeal."[168] In that year, Cambridge lecturer, William Henry Besant, presented a paper on "The Teaching of Elementary Mechanics;" the Royal Indian Engineering College Professor, George Minchin, gave "Notes on the Teaching of Elementary Dynamics;" and Horace Lamb, from the University of Adelaide, contributed "The Basis of Statics." In the following nine years, the *AIGT Report* printed, among others, papers by Charles Taylor on "The Discovery and the Geometrical Treatment of Conic Sections;" Harrow School Master, Robert Baldwin Hayward, on "The Correlation of the Various Branches of Elementary Mathematics;" University College, Aberdeen Professor, Robert William Genese, on "Elementary Mechanics;" and Alfred Lodge, another Royal Indian Engineering College Professor, on "The Multiplication and Division of Concrete Quantities."[169]

During the 1890s, the AIGT renamed itself as the Mathematical Association and its *Report* developed into a proper journal, called the *Mathematical Gazette.* These changes reflected the Association's widened interests in mathematics and pedagogy.

---

[167]T.A.A. Broadbent, "The *Mathematical Gazette*: Our History and Aims," *Mathematical Gazette*, 186-194 on p. 186.

[168]Michael Price, p. 38.

[169]A listing of these papers is found in "Publications Issued by the Association for the Improvement of Geometrical Teaching," reproduced in Michael Price, p. 37.

The *Gazette*'s first editor and schoolmaster at Bedford Moderate School, Edward Mann Langley, wrote in the first volume of 1894 that "[w]e hope to extract from desk and pigeon-hole many MSS, which have remained unpublished for want of a suitable organ for making them known... But we intend to keep strictly to 'Elementary Mathematics': while not absolutely excluding Differential and Integral Calculus, our columns will, as a rule, be devoted to such school subjects as Arithmetic, Algebra, Geometry, Trigonometry, and Mechanics."[170]

The *Gazette* served dual functions as a minor mathematical serial and an educational journal.[171] Along with mathematical articles on the subjects described above by Langley, it contained valuable book reviews, historical notes, and questions for solution. The *Gazette*'s educational content, as calculated by Michael Price, varied from 3% to 16% for the nineteenth century.[172]

Besides the Mathematical Association, another British mathematical society emerged during the last third of the nineteenth century to further the agendas of mathematical educators. The Edinburgh Mathematical Society (EMS) began in 1883 with the goal of "the mutual improvement of its members in the Mathematical Sciences... [through] [r]eviews of works both British and Foreign, historical notes, discussion of new problems or new solutions, and comparison of the various systems

[170]E.M. Langley, "Origin of the Mathematical Gazette," *Mathematical Gazette* 1 (1894), quoted in Michael Price, p. 40.

[171]For more on British minor mathematical serials, see chapter 3.

[172]Michael Price, p. 64. "Taking educational contributions to include correlation with other subjects the examination system, teacher supply and education, and educational research," Price calculates that 12% of the *Gazette* was educational for 1894 and 1895, 16% for 1896-97, 10% for 1898-99, and 3% for 1900. Questions for answer in the *Gazette* "became virtually extinct" after 1908. *Ibid.*, p. 65.

countries, or any other means tending to the promotion of mathematical Education."[173] Its two founders, Alexander Fraser and Andrew Barclay worked as mathematical masters in an Edinburgh school, and their profession was shared by 40 of the Society's first 58 members.[174] Unlike those of its fellow mathematical society in London, nineteenth-century officers of the Edinburgh Mathematical Society did not occupy the highest positions in other major scientific societies.[175] In fact, seven of its first ten presidents were school teachers.[176]

In accordance with the Society's initial objectives and the profession of most of its membership, the *Proceedings of the Edinburgh Mathematical Society* contained pedagogical, historical, and many geometrical articles.[177] In fact, of the reviews of this journal in the *Jahrbuch über die Fortschritte der Mathematik*, two-thirds of the nineteenth-century articles concerned these topics.[178] An EMS committee presented a report "On the Teaching of Arithmetic."[179] Frequent contributors included the schoolmasters John Mackay and Arthur Pressland, both of the Edinburgh Academy, and George Crawford, of the Harrow School. The *Proceedings* also published the

[173] Cargill G. Knott, Andrew J.G. Barclay, and Alexander Y. Fraser, "Circular, January 23, 1883;" quoted in Robert A. Rankin, "The First Hundred Years," *Proceedings of the Edinburgh Mathematical Society* 26 (1983): 135-150 on p. 136.

[174] Rankin, pp. 135, 137. Even in 1926, the percentage of university members of the Society was only 36%.

[175] Specifically, no nineteenth-century President, Treasurer, or Secretary of the Edinburgh Mathematical Society served in the same offices in the Royal Society of London, the Royal Society of Edinburgh, or the BAAS; likewise these officers filled no nineteenth-century presidency in the Royal Irish Academy.

[176] Rankin, p. 137.

[177] *Ibid.*, p. 140.

[178] 37% of the nineteenth-century articles concerned "Pure, Elementary, and Synthetic Geometry," 15% dealt with "Analytic Geometry," and 14% discussed "History and Philosophy" (a *Jahrbuch* category that included pedagogy). For more on the *Jahrbuch* classifications, see chapter 7.

[179] Alexander Yule Fraser, *et. al.*, "On the Teaching of Arithmetic," *Proceedings of the Edinburgh Mathematical Society* 6 (1888): 89-102.

articles of those well within the university sphere such as Peter Guthrie Tait and George Chrystal, Professors of Natural Philosophy and Mathematics, respectively, at the University of Edinburgh, and James Steggall, Professor at University College, Dundee.

The remarks of another contributor to the *Proceedings of the EMS*, Thomas Muir, suggest that the society's stated objective of "the mutual improvement of its members in the Mathematical Sciences" may have been laced with the fears of a Scottish mathematical "brain drain." Muir, Mathematical Master at Glasgow High School, lamented in his presidential address to the EMS that

> A Scotch University student who has a special taste for mathematics, and has come to the University to develop that taste, has usually something like the following career... [At his university] he obtains a knowledge of Synthetic and Analytical Conics, the elements of Differential Calculus, and, it may be, of the Integral Calculus as well. He knows there is no hope for him if he does not take his Master of Arts degree, and he gives his attention to Classics and Mental Philosophy... continuing by himself his reading in Mathematics as far as it may be possible to do so. In time he graduates: this entitles him to compete for a scholarship: he competes, and is successful, leaves for Cambridge and his University knows him no more. Probably in the newspapers we observe that Mr. Donald Scott of a certain northern university has gained an open scholarship ... and the competition having been between him and a number of young men fresh from English public schools, we are gratified accordingly with his startling success. Gentlemen, I put it to you, if this is a thing for us as Scotsmen to be altogether proud of. When in these cases a young Scotch student competing with English students *of the same age* gains a scholarship, there may be cause for gratulation: but the Scotsman who glories in the part his Universities play in the matter glories in his own shame. Is it really past hoping for that all this may yet be changed?[180]

The establishment of the EMS and its *Proceedings* helped enrich a Scottish mathe-

[180]Thomas Muir, quoted in Rankin, p. 138. For more on Scottish mathematical education, see chapter 5.

matical environment that had been overshadowed by Cambridge, and it helped many Scottish mathematicians become active members of the British mathematical publication community.

While they were founded for different specific reasons, the Mathematical Association and the mathematical societies of Edinburgh and London all emerged in response to a growing group of scholars who increasingly identified themselves with the discipline of mathematics. Within a relatively short period, British mathematics gained access to three societies that specifically catered to its needs at both the research and educational levels. Together with the multifaceted BAAS, the Royal Astronomical Society, and the grand old general scientific societies, these mathematical societies provided the British mathematical publication community with a wide spectrum of outlets for the communication of mathematics.

Conclusion

While considering the defects of scientific societies, Charles Babbage also evaluated the factors that rendered them useful for scientists:

> There are several circumstances which concur in inducing persons pursuing science to unite together, to form societies or academies. In former times, when philosophical instruments were more rare, and the art of making experiments was less perfectly known, it was almost necessary. More recently,. . . it has been found that those who are most capable of expending human knowledge, are frequently least able to encounter the expense of printing their investigations. It is therefore convenient, that some means should be devised for relieving them from this difficulty, and the volumes of the transactions of academies have accomplished the desired end.[181]

[181]Babbage, p. 15.

Throughout the nineteenth century, mathematicians seized the publication opportunities offered by British scientific society journals. Although the absence of a publishing mathematical society left mathematicians to compete with writers from different areas of science for room in society journals for the first half of the century, mathematical papers formed a substantial proportion of these journals' pages. Through their work as referees, authors, and officers, mathematical members of these societies carved out a place for their discipline in the society publication venue.

While they had no major mathematical society of their own before 1865, British mathematicians had three from which to choose by 1883. These new societies allowed mathematicians to discuss freely research that other scientists found increasingly difficult to follow. The meetings of the EMS and AIGT also allowed its members to discuss issues specific to teaching mathematics.

In embracing these new societies, however, British mathematicians did not end their affiliations with other scientific societies. Even during the last third of the nineteenth century, the *Philosophical Transactions* was still a premier destination for mathematical articles. As their publications, and their work as society officers show, nineteenth-century British mathematicians felt the need to work within their discipline and within the general scientific community.

CHAPTER 3: BRITISH MATHEMATICS IN COMMERCIAL JOURNALS

Outside of Societies: Nineteenth-Century British Independent Journals

While members of the nineteenth-century British mathematical publication community utilized the journals of scientific societies, they also took advantage of a venue that did not require a society membership or a formal communication. Independent scientific periodicals provided a considerable publication outlet during the nineteenth century; in fact, by one estimate, 64% of the British scientific journals from 1824 to 1900 were commercial ventures.[1] Commercial scientific journals had a variety of features that made them attractive to contributors:

> They speeded up publication at times when the proceedings of scientific societies appeared intermittently, or only once or twice a year; they provided intelligence of science in foreign journals for those who had no access to large libraries; they aired controversies and allowed the issues involved to be resolved promptly; they accepted for publication the minor, and sometimes, trivial research with which learned societies could not be bothered, thereby continuing to cater for the popular and cultural images of science when it was undergoing the rigour of specialization; on the other hand, they often accepted for publication original findings or theoretical speculations that were considered unorthodox by societies. In that respect they kept the scientific societies on their toes, broke their monopolies, and made them less authoritarian and cliquish than they might have been.[2]

A review of the journals listed in the *Waterloo Directory* of English, Irish, and Scottish newspapers and periodicals of the nineteenth century as well as those covered in Raymond Archibald's 1929 overview of mathematical serials reveals that mathe-

[1] William H. Brock, "The Development of Commercial Science Journals in Victorian Britain," in *Development of Science Publishing in Europe*, ed. Arthur Jack Meadows (Amsterdam: Elsevier Science Publishers, 1980), pp. 95-102 on p. 95.

[2] *Ibid.*

matical writers enthusiastically embraced British commercial journals.[3] At least 103 of these nineteenth-century periodicals included mathematics among their pages. In most cases, mathematics appeared side by side with articles concerning other scientific topics as well as poetry, prose, biography, book reviews, and articles on education, history, religion, and agriculture.[4] The average lifespan of these periodicals was about 17 years, but over half of them survived less than five years.

This chapter examines the establishment, organization, and operation of a subset of these journals. One section investigates the *Philosophical Magazine* as a representative example for understanding the mechanics of commercial scientific journal publication. Specifically, this section concerns the bureaucratic and financial hurdles the journal encountered as well as the journalistic methodology it employed. It analyzes how the journal matured through its changing editors, and how the journal's coverage of mathematics changed. Another section considers the role of the journal *Nature* not as a vehicle for the publication of original research but as a mouthpiece for British mathematicians during the last third of the nineteenth century. Finally, this chapter focuses on what Archibald considered "minor mathematical serials" that encompassed scientific journals, almanacs, and newspaper columns. Besides looking

[3]John S. North, *Waterloo Directory of English Newspapers and Periodicals 1800-1900*, 10 vols. (Waterloo: North Waterloo Academic Press, 1997); John S. North, *Waterloo Directory of Scottish Newspapers and Periodicals 1800-1900*, 2 vols. (Waterloo: North Waterloo Academic Press, 1989); John S. North, *Waterloo Directory of Irish Newspapers and Periodicals 1800-1900* (Waterloo: North Waterloo Academic Press, 1986); Raymond Archibald, "Notes on Some Minor English Mathematical Serials," *Mathematical Gazette* 14 (1929): 379-400.

[4]Of the journals uncovered, at least 52 contained articles on literary topics, 36 on other scientific topics, 25 on biography or book reviews, 20 on education, 20 on weather, agriculture or domestic matters, 17 on history, 15 on puzzles, enigmas, or rebuses, 11 on politics, nine on religion, and nine on the fine arts.

closely at a few examples, it discusses the content, contributors, editors, and financial perils of these journals.

The Mechanics of Commercial Scientific Journal Publication: The Case of the *Philosophical Magazine*

While the nineteenth-century publication environment experienced unprecedented growth in British commercial scientific journals, it was soon "littered with dead or dying journals which had attempted to capture the readership of a growing scientific community."[5] One journal that survived in this precarious environment, the *Philosophical Magazine*, provides an example of the business sense, scientific connections, and flexibility necessary for the success of a nineteenth-century British independent scientific periodical.

In 1798, entrepreneur Alexander Tilloch established the *Philosophical Magazine: Comprehending the Various Branches of Science, the Liberal and Fine Arts, Geology, Agriculture, Manufactures and Commerce* as a shameless imitation of *A Journal of Natural Philosophy, Chemistry and the Arts.* The latter journal, generally referred to as *Nicholson's Journal*, was founded a year before the *Philosophical Magazine* by William Nicholson and provided speedy publication of results often within the same month they were written.[6] In fact, Nicholson provided abstracts of papers read to the Royal Society months before these papers appeared in the *Philosophical Trans-*

[5]Bernard Houghton, *Scientific Periodicals: Their Historical Development, Characteristics and Control* (London: Clive Bingley, 1975), p. 24.

[6]Before this publication endeavor, Nicholson had begun a mathematics school, written a textbook, compiled two chemistry dictionaries, translated foreign works, and created inventions; in the journal's third year, he performed the first electrolysis of water with surgeon, Anthony Carlisle. Samuel Lilley, "Nicholson's Journal (1797-1813)," *Annals of Science* 6 (1948): 78-101 on pp. 82, 84.

actions.[7] As a prompt report of science, *Nicholson's Journal* also became a forum for airing scientific controversies and served as a clearinghouse for the "the popular movement, with its host of small significant contributions totaling a considerable portion of the whole."[8]

Tilloch acknowledged his intentions to follow his predecessor's pattern on the title page of his magazine, through a Latin quotation that stated, "[t]he way the spiders weave, you see, is none the better because they produce the threads from their own body, nor is ours the worse because like bees we cull from the work of others."[9] Tilloch's scientific "pollen" included reprinted articles from foreign and domestic journals as well as abstracts of papers read to scientific societies. The *Philosophical Magazine* surpassed *Nicholson's Journal* in this condensation of scientific material and subsequently became a commercial success.[10] While led by a credible scientist, *Nicholson's Journal* was plagued with financial problems and, in 1814, was incorporated into its rival. Tilloch announced that this amalgamation would remedy redundant communications that imposed "increased expense upon many of our readers."[11] According to Tilloch, he and Nicholson had decided that "it would certainly be best that we should unite, and that the joint product of our exertions and our correspondence should be consolidated in one periodical work... *The Philosophical Journal*

[7] *Ibid.*, pp. 91, 95.

[8] *Ibid.*, p. 79, 91.

[9] William H. Brock and Arthur Jack Meadows, *The Lamp of Learning: Taylor & Francis and the Development of Science Publishing* (London: Taylor & Francis, 1984), p. 218. The quotation is from Justus Lipsius, a Belgian writer of the sixteenth century. This extract appeared in the *Philosophical Magazine* long after it became an organ for original research; it was removed only after the journal was reorganized in 1949. *Ibid.*, p. 205.

[10] *Ibid.*, p. 81; and Lilley, p. 95.

[11] "Advertisement," *Philosophical Magazine* 42 (1813).

will henceforth be discontinued; and *The Philosophical Magazine* will be conducted by WILLIAM NICHOLSON and ALEXANDER TILLOCH, in the same manner as it has always been carried on; but with every attention to improvement which the joint exertions of the Editors, and the communications of their friends and correspondents can afford."[12] In fact, Tilloch became the sole editor of the combined journal when Nicholson died the year after this consolidation.[13]

The *Philosophical Magazine* was just one of a series of Tilloch's varied business enterprises. In the years after his 1771 graduation from the University of Glasgow, he had invented and patented a stereotype printing method, and he had bought and begun editing the London newspaper, *The Star*.[14] Tilloch's editorial duties with this newspaper and the *Philosophical Magazine* did not prevent him from patenting steam machines and proposing anti-counterfeiting schemes to the Bank of England and the French government.[15] The founder of the *Philosophical Magazine*, then, was an enterprising businessman and inventor willing to pursue and create a variety of ventures.

Since 1800, another enterprising businessman, Richard Taylor, had acted as Tilloch's printer for the *Philosophical Magazine*.[16] Taylor had risen through the ranks of the printers' trade to become a respected London citizen. In 1822, Tilloch made Taylor

[12] *Ibid.*

[13] Brock and Meadows, p. 82.

[14] *Ibid.*, p. 79. This printing method had actually been anticipated in 1725 by William Ged, a jeweler from Edinburgh, and Tilloch was unsuccessful in widely promoting its use.

[15] *Biographie universelle, ancienne et moderne* (Paris: A. T. Desplaces, 1843-1865), s.v. "Tilloch (Alexandre)."

[16] Brock and Meadows, p. 79.

co-editor and co-proprietor of his *Magazine* and left Taylor the entire enterprise upon his death three years later. Under Taylor's leadership, the *Philosophical Magazine* absorbed the *Annals of Philosophy* in 1826 and the *Edinburgh Journal of Science* in 1832. While the *Annals of Philosophy,* founded in 1813 by the Scottish chemist Thomas Thomson, proved to be a formidable competitor to the *Philosophical Magazine*, the move of its founder from London to Glasgow in 1817 after being elected to the University of Glasgow's Regius Chair of Chemistry marked the journal's decline.[17] David Brewster had founded the *Edinburgh Journal of Science* in 1824 as a rival to the *Edinburgh Philosophical Journal* after being removed as one of its editors; this new journal met with trouble almost immediately.[18] Through these journal takeovers, Taylor enlisted the editorial services of the defunct journals' editors, Richard Phillips and David Brewster.[19] With Brewster in Edinburgh and Phillips and himself in London, Taylor recruited Robert Kane, founder and previous editor of the *Dublin Journal of Medical and Chemical Science.* This "completed the British university city triangle, making the *Philosophical Magazine* into the corporate journal for all British science."[20]

By 1840, *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science* had survived stiff competition and carried as a symbol of its success a title reflective of its multiple amalgamations. One factor for this success was the high standing its editors held within British scientific circles. Tilloch was a mem-

[17] *Ibid.*, pp. 82-83.
[18] *Ibid.*, pp. 84-85.
[19] *Ibid.*, p. 84.
[20] *Ibid.*, p. 86.

ber of the London Philosophical Society, the British Mineralogical Society, and the Askesian Society, of which the latter two combined to form the Geological Society in 1807. Likewise, Taylor had close ties with the Linnean, Geological, and Royal Astronomical Societies; these connections helped strengthen the magazine's coverage of the disciplines associated with these societies.[21] David Brewster also brought scientific clout to the *Philosophical Magazine.* By 1831, he was recognized for his work in experimental optics and was instrumental in encouraging British scientists to form the British Association for the Advancement of Science.[22] Phillips became a Fellow of the Royal Society in 1822 and lectured on chemistry at the Royal Military College in Sandhurst, the Royal Institution, and London hospitals,[23] while Kane had been trained in Giessen under the German chemist, Justus von Liebig.[24] All three of the editors acquired through Taylor's journal takeovers carried out their editorial duties to the *Philosophical Magazine* for the rest of their lives.

In 1852, Taylor welcomed his son, William Francis, as a partner in his business.[25] Like his father, Francis was respected within the British scientific community. While

[21] *Ibid.*, pp. 81,83. Taylor was Undersecretary (1810-1857) and a Fellow of the Royal Astronomical Society (1820). Taylor (and later his company) printed the *Transactions* of the Linnean Society (1800-1950), the *Transactions* (1822-1950) and *Proceedings* (1834-1950) of the Geological Society, and the *Memoirs* of the Royal Astronomical Society (1822-1829). In 1832, Taylor began publishing the *Reports* of the BAAS and later became the official printer of the Royal Society (he printed all of their publications from 1828 to 1877) and the University of London (1836-1900). *Ibid.*, pp. 37-48, 91.

[22] Jack Morrell and Arnold Thackray, *Gentlemen of Science: Early Years of the British Association for the Advancement of Science* (Oxford: Clarendon Press, 1981), pp. 58-59, 534.

[23] *J.C. Poggendorff's Biographisch-Litterarisches Handwörterbuch* (Leipzig: Verlag von Johann Ambrosius Barth, 1863-1926), s.v. "Phillips, Richard."

[24] Brock and Meadows, p. 86.

[25] Around 1816, Richard Taylor was involved with a Mrs. Francis, with whom he had two children, William and Rachel. Although some of Taylor's family and friends knew of his relationship to William Francis, he publicly hid the fact that Francis was his son; even his will was written to keep this fact secret. *Ibid.*, pp. 30, 119.

he apprenticed in the family business as a teenager, in 1839, Francis augmented his practical training in printing with scientific training at the University of Berlin. After specializing in chemistry, he moved to the University of Giessen and obtained a doctorate under Liebig in 1842. Taylor put this continental education to work for his business even before his son had graduated; as a student, Francis sent home translations of scientific memoirs by German scientists. Despite his training, Francis wrote only a few original contributions before turning his attention exclusively to what would become known after 1852 as Taylor & Francis.[26]

After Taylor's death in 1858, Francis took over the firm and managed a growing group of editors for the *Philosophical Magazine.* A family friend and part of the "young guard of science," John Tyndall, began a ten-year stint as editor in 1854. Francis' fellow alumnus of Giessen's chemistry program, Augustus Matthiessen, joined the team in 1869 and served until his death a year later. Later in the nineteenth century and in the beginning of the twentieth, several editors, namely Lord Kelvin, Oliver J. Lodge, and Joseph John Thomson, "lent as editors the power of their names to promote the influence of the *Magazine*, while the support of Ireland was evidenced by the inclusion of [George Francis] Fitzgerald and John Joly. It is doubtful if these great men took any active part in the running of the paper, especially as they mostly lived at some distance from London, but they were available for consultation, and the presence of their names was a guarantee of the confidence felt by the scientific world in the conduct of the paper."[27]

---

[26] *Ibid.*, pp. 100, 102-103, 106, 110.

[27] "The Philosophical Magazine," *Endeavour* 8 (1949): 1-2 on p. 1. The editorial tenures for

The recognition and support that Taylor & Francis enjoyed from British men of science did not ensure the success of their scientific journals; in fact, taxes levied by the government on several aspects of journal production and distribution crippled the profits of the *Philosophical Magazine* as well as other scientific periodicals during the first half of the nineteenth century. Beginning in 1711, publishers of newspapers and journals in Britain were forced to pay a stamp tax on each copy of a given edition and "while the tax remained in existence it obstructed the circulation of journals to a greater extent than any other single factor."[28] Accompanying the stamp tax were other "taxes on knowledge" including an excise duty and a tax on advertisements. On top of taxes, before postal reforms in 1840, "the receipt and distribution of letters and proofs, of packets and books, and the finished periodical itself, was an uncertain, risky and costly business."[29]

As a witness to the Select Committee on Postage in March 1838, Taylor testified that "[t]he fact is, scientific journals in this country are supported with very great difficulty; they can hardly be supported at all."[30] Taylor had witnessed the demise of the three journals he had absorbed, as well as the *Royal Institution Quarterly Journal*, the *Records of Science* "and others; they have all of them failed from an inability to cover their expense and it is almost an impracticable thing to keep a

these scientists were: Kelvin (1871-1907), Lodge (1911-1940), J.J. Thomson (1911-1940), Fitzgerald (1890-1901), and Joly (1901-1933).

[28]J. Don Vann and Rosemary T. VanArsdel, ed., *Victorian Periodicals: A Guide to Research* (New York: Modern Language Association of America: 1978), p. 156. Brock suggests that this tax may have inhibited the growth of provincial science periodicals since, under the tax, paper had to be bought from Stamp Offices located in metropolitan areas. Brock, "Development," p. 98.

[29]Brock, "Development," p. 100.

[30]Richard Taylor, "First Report of the Select Committee on Postage," *Parliamentary Papers*, 1837-1838, in Brock and Meadows, p. 88.

scientific journal alive in this country.... I do not think the journal to the editorship of which I succeeded, the Philosophical Magazine, could have been supported if I were not at the same time the editor, printer and publisher. It has never more than just covered its expenses."[31]

Taylor did receive some relief through postal reforms in 1849. As announced in the *Philosophical Magazine*, "[t]he speedy and cheap transmission of intelligence is of the highest importance for the interest of science... We are glad to find that the subject has at length received attention from the authorities of the Post-office, and that some important improvements have been lately introduced."[32] Growing pressure for tax reform had resulted in the reduction of many of these taxes in the 1830s and their repeal in the 1850s. The following decades, "not surprisingly, were marked by an explosion of popular journalism that saw vastly increased circulations and considerably reduced prices."[33]

Taylor also responded to this improving environment for scientific journals when he began the *Scientific Memoirs* in 1837. He saw this journal as a solution to the problem of making British scientists aware of scientific work from abroad while not decreasing space for original British articles in the *Philosophical Magazine*. [34] British mathematicians applauded Taylor's new venture and offered to help choose and translate what they considered as the most important foreign mathematical memoirs for British readers.

[31] *Ibid.*, p. 89.
[32] "Post-Office Regulations," *Philosophical Magazine* 3rd ser., 34 (1849): 158-159 on p. 158.
[33] Vann and VanArsdel, p. 157.
[34] Brock and Meadows, pp. 89-90.

Writing to Taylor in March 1838, William Rowan Hamilton remarked that, "in an inaugural address which I delivered lately, as President, to the Royal Irish Academy, I called attention to the too great isolatedness which at present exists between the various learned bodies of the world; & spoke of your *Scientific Memoirs*, as a work which it might perhaps be expedient for us to interfere, as a body, to encourage."[35] As a result, the Royal Irish Academy decided to subscribe permanently to 20 copies of the new journal.[36]

A year later, Trinity College, Dublin graduate James Booth wrote to Taylor in order to direct the journal's mathematical contents. "[P]erceiving that translations of some of the first Continental treatises appear from time to time in your 'Scientific Memoirs'," Booth wondered if Taylor would "approve of a translation with notes of Poisson's celebrated treatise on the Calculus of Variations, which appeared ... in the ... Memoirs of the Institute and which from the bulk and congruent high price of the volume in which it is to be only found is at present inaccessible to the generality of English readers."[37] Similarly, Cambridge graduate Alfred W. Hobson, offered, "[i]f there are any French Memoirs on Mathematical subjects which you may contemplate introducing into the 'Scientific Memoirs' – and my service can be of any use, I shall be happy to render them – of course I do not make this offer with any view to pecuniary renumeration... My object is to aid – if possible in the continuation of the

[35] William Rowan Hamilton to Richard Taylor, Taylor & Francis Papers, St. Brides Library, London, 8 March 1838.

[36] *Ibid.*

[37] James Booth to Richard Taylor, Taylor & Francis Papers, St. Brides Library, London, 21 November 1840.

'Memoirs' which is I think a work of very great importance. I believe that Fresnel's *Memoir on the Undulatory Theory* has not yet been translated. Could this be selected?"[38] Proof that Taylor sought advice from mathematicians about the content of *Scientific Memoirs* comes from a letter from Plumian Professor of Astronomy at Cambridge, James Challis. After reading the memoir on hydrodynamics of the Italian mathematician, Placido Tardy, Challis remarked that "it shews great mathematical talent, and complete acquaintance with the present advanced state of analysis. I do not, however, recommend its being translated for the Scientific Memoirs. It is too exclusively mathematical."[39]

Taylor again established a new journal in order to conserve space in the *Philosophical Magazine* when he began the *Annals of Natural History* in 1838. William Francis had convinced his father to begin this new biological venture and also persuaded him to found the *Chemical Gazette* in 1842.[40] Thus, two traditional subject areas for articles in the *Philosophical Magazine* were diverted into separate journals.

While the lifting of taxes and the easing of postal charges encouraged Taylor to launch new journals, other costs and high competition continually imperiled these business ventures. One problem rested with libraries. Since charging libraries a higher

[38] Alfred W. Hobson to Richard Taylor, Taylor & Francis Papers, St. Brides Library, London, 4 February 1847. Hobson was commissioned by Taylor to translate some of Fresnel's work. Augustin Fresnel, "Memoir upon the Colours Produced in Homogeneous Fluids by Polarized Light," *Scientific Memoirs* 5 (1852): 44-65; and "Memoir on Double Refraction," *Scientific Memoirs* 5 (1852): 238-333. After completing his translation, Hobson was aided by Sylvester in proofreading "to ensure that no error escape[s] without notice." Alfred W. Hobson to Richard Taylor, Taylor & Francis Papers, St. Brides Library, London, 11 October 1847.

[39] James Challis to Richard Taylor, Taylor & Francis Papers, St. Brides Library, London, 24 March 1848.

[40] Brock and Meadows, pp. 106-107, 114.

institutional rate was only a twentieth-century convention, the *Philosophical Magazine* lost individual subscriptions without being compensated in its sales to libraries.[41] In fact, individual reader subscriptions to the *Philosophical Magazine* amounted to only 18 in 1851.[42]

Taylor utilized the practice of serializing his journal in order to encourage more readers. He described this marketing strategy as "convenient periodical starting points for new readers, desirous of subscribing to the Journal, but deterred from doing so by their objection to beginning with a volume having a high number on its title page."[43] Besides offering its journal in series, Taylor & Francis also serialized the articles themselves. This practice served "not only to conserve space and permit a variety of material to be printed in one issue, but [also] deliberately to ensure that the interested reader would purchase the next issue."[44]

Despite these marketing measures, not all Taylor & Francis journals had the longevity of the *Philosophical Magazine.* While celebrated by mathematicians and other scientists, the *Scientific Memoirs* brought lower-than-expected sales and con-

---

[41]Brock, "Development," p. 108.

[42]*Ibid.*, p. 107. By 1905, there were 201 personal subscribers to the journal. Certainly, many issues of the *Philosophical Magazine* were sold to non-subscribers. Print runs can give another indication of the number of readers of the *Philosophical Magazine.* Brock and Meadows record a print run of 1000 copies in 1813, 500 in the 1820s under Taylor's direction, 650 in the 1850s, then back down to 550 in the 1860s. Many of these issues were sold as back copies years later. Brock and Meadows, pp. 88, 124.

[43]Richard Taylor, *Annals of Natural History* (3) 1838; quoted in Brock and Meadows, p. 97. The *Philosophical Magazine* ran through five series during the nineteenth century: volumes 1-68 (June 1798-1826); new series, volumes 1-11 (1827-June 1832); 3rd series, volumes 1-37 (July 1832-1850); 4th series, volumes 1-50 (1851-75); 5th series, volumes 1-50 (1876-1900). In the twentieth century, there were only three additional series: 6th series, volumes 1-50 (1901-25); 7th series, v. 1-46 (1926-55); 8th series, volumes 1-36 (1956-1977). After 1977, the *Philosophical Magazine* did not move to a new series but divided into parts A and B.

[44]Brock, "Development," p. 97.

siderable financial loss for Taylor with its inaugural volume. Even with monetary assistance for the second volume from the British Association for the Advancement of Science, the *Scientific Memoirs* continued to be a liability for Taylor & Francis. Francis ended the journal's publication with its seventh volume in 1853, and it would be 1875 before the company recovered its losses through sales of back copies.[45] The loss of his co-editor, Henry Croft, to the Chair of Chemistry at the University of Toronto, together with Taylor's death, also compelled Francis to sell the *Chemical Gazette* in 1858.[46]

Unlike some of its sister publications at Taylor & Francis, the *Philosophical Magazine* managed to brave the competitive, scientific journal environment. Mathematics accompanied the journal on its journey through the nineteenth century, and the extent of its presence in the *Philosophical Magazine* changed with the needs and business decisions of Taylor & Francis.

In the first part of the nineteenth century, mathematical articles were forced to vie for room in the *Philosophical Magazine* with those from a wide range of other disciplines. The spectrum of subjects covered in the magazine can be inferred from the 1827 version of its title, *The Philosophical Magazine or Annals of Chemistry, Mathematics, Astronomy, Natural History and General Science.* An analysis of the *Philosophical Magazine* shows that mathematics, not surprisingly in the face of this competition, occupied only a small share of the journal's pages during the early

[45]Brock and Meadows, pp. 91-92.
[46]*Ibid.*, p. 115.

nineteenth century (see Table 3A).[47] Besides competition, the reasons for this small percentage may have also derived from an articulated policy by Taylor to minimize his journal's coverage of mathematics.[48] In a notice printed in the *Philosophical Magazine* in 1846, the editors put mathematics in its place:

> In the admission of mathematical articles, the Editors are obliged to consult both quantity and character, as follows: It is not in their power to admit any very great quantity of pure mathematics. The majority of the readers of the Magazine are more interested in other sciences, and the Magazine would soon cease to exist if it were more than sparingly supplied with articles on lofty mathematical subjects.[49]

In fact, this reaction stemmed more from an aversion to controversy than to mathematics. The notice continued:

> As to the character of their mathematical articles, the Editors are placed in a peculiar position. They do not themselves profess to be so conversant with the higher mathematics as to rely entirely on their own judgement. In the articles which they insert, they must be guided by opinions. If they occasionally insert an article in which the general opinions of mathematicians are controverted, it is because they feel that mathematicians themselves would occasionally like to see the manner in which dissent from generally received principles manifests itself; and because they know that such occasional insertion will not, in the eyes of the same mathematicians, make them, the Editors, appear to be assuming a side in controversies of the merits of which they are not sufficient judges. But if the Editors were to lend their Magazine to an extensive system of attack upon any usual

[47]The classification scheme for Table 3A is adopted from that of the *Jahrbuch über die Fortschritte der Mathematik*, a mathematical review journal established in 1868. Moreover, the analysis of the articles for the table's last period, 1868-1900, come from the reviews printed in the *Jahrbuch*. For more on the *Jahrbuch*, the classifications, and periodization presented in Table 3A, see chapter 7. The trends shown in this table agree well with Helena Nešetřilová's study of the journal from 1800 to 1850, even though her classification scheme is slightly different. Through an exhaustive survey of the issues of the *Philosophical Magazine* from 1800 to 1850, she found that mathematics occupied less than 6% of the magazine's total production before 1840, then climbed to over 12% of the production by 1850. Helena Nešetřilová, "*Philosophical Magazine* a anglická mathematika v letech 1800-1850" ("*Philosophical Magazine* and English Mathematics of 1800-1850"), *DVT, Dějiny věda techniky* 7 (1974): 83-100 on pp. 85-86.

[48]Brock and Meadows, p. 87.

[49]"Observations on the Subject of the Preceding Communications," *Philosophical Magazine* 3rd ser., 28 (1846): 145-146 on p. 146.

results and methods of mathematics, wither pure or mixed, they feel that they could not escape the charge of presumption... They would suggest both assailants and defendants to carry their communication to quarters in which they will find more competent judges. The pages of the Philosophical Transactions, or the Memoirs of the Royal Irish Academy, or the Cambridge Philosophical Society, of the Cambridge Mathematical Journal, &c., are much fitter vehicles for extensive mathematical discussion than those of the Philosophical Magazine.[50]

Table 3A: Mathematical Content of the Philosophical Magazine, in Pages

Mathematical Area*	1800-1836	1837-1867	1868-1900
Mathematical Physics	356	1,848	4,688
Mechanics	120	611	878
Geodesy and Astronomy	888	442	367
Algebra	98	784	116
Analytic Geometry	56	473	254
Differential and Integral Calculus	123	327	214
Pure, Elementary, and Synthetic Geometry	158	139	85
Combinatorics and Probability	65	239	162
History and Philosophy	96	341	33
Number Theory	31	149	70
Function Theory	57	100	62
Series	41	86	56
Other	51	34	0
Total Math'l Pages	2,140	5,573	6,985
% of Math'l Pages in *Phil. Mag.*	5.9%	16.1%	20.3%

* These mathematical areas are adopted from the *Jahrbuch über die Fortschritte der Mathematik.* For more on the *Jahrbuch*, the classifications, and periodization presented in Table 3A, see chapter 7.

Mathematicians commonly used the *Philosophical Magazine* as a forum in which to air grievances. One such instance surrounded a contentious physical issue that continued into the first half of the nineteenth century concerning the question of whether light resulted from particle streams or the vibrations of waves in a medium.[51] Around

[50] *Ibid.*

[51] This issue led to spirited controversies and fruitful developments in physics during the nineteenth and twentieth centuries. For more information on controversies surrounding the theory of light during the nineteenth century, see Jed Z. Buchwald, *The Rise of the Wave Theory of Light: Optical Theory and Experiment in the Early Nineteenth Century* (Chicago: University of Chicago Press, 1989).

1821, the French engineer and mathematician, Augustin Fresnel, created a theory of light supporting the wave hypothesis that best explained the new experimental findings on the phenomenon of double refraction. The construction of the wave surface for this theory was greatly simplified in an 1830 paper in the *Transactions of the Royal Irish Academy*, "On the Double Refraction of Light in a Crystallized Medium According to the Principles of Fresnel," by a recent Trinity College, Dublin (TCD) graduate, James MacCullagh.[52]

William Rowan Hamilton, another recent TCD graduate and new holder of the Andrews Chair of Astronomy, was also interested in constructing this wave surface. In the process of his investigations, he successfully predicted the existence of a cone of rays emanating from a biaxial crystal under the right conditions. After announcing this discovery to the Royal Irish Academy in October, 1832 and publishing it in their *Transactions*, Hamilton enjoyed "immediate international recognition."[53] After being informed of Hamilton's work, MacCullagh found that the phenomenon of conical refraction was easily deducible from his earlier work on Fresnel's wave surface. Irritated that he had been beaten to the punch, MacCullagh published a provocative complaint

[52]T.D. Spearman, "Mathematics and Theoretical Physics," in *The Royal Irish Academy: A Bicentennial History*, ed. T. Ó Raifeartaigh (Dublin: The Royal Irish Academy, 1985), pp. 201-239 on pp. 209-210. James MacCullagh, "On the Double Refraction of Light in a Crystallized Medium According to the Principles of Fresnel," *Transactions of the Royal Irish Academy* 16 (1832): 65-78. For more on MacCullagh's pure mathematical work, see chapter 6.

[53]T.D. Spearman, "James MacCullagh," in *Science in Ireland 1800-1930: Tradition and Reform*, ed. John R. Nudds *et. al.* (Dublin: Trinity College Dublin, 1988), pp. 41-60 on p. 45. William Rowan Hamilton, "Third Supplement to an Essay on the Theory of Systems of Rays," *Transactions of the Royal Irish Academy* 17 (1837): 1-144. For Hamilton's celebrated first paper "On the Theory of Systems of Rays," see chapter 2. For an account of Hamilton's discovery conical refraction by one of Hamilton's contemporaries, recall Robert Percival Graves, *Life of Sir William Rowan Hamilton* (Dublin: Hodges, Figgis, & Co., 1882), pp. 623-638.

in the *Philosophical Magazine* that Hamilton "did not seem to have been aware that it [conical refraction] is an obvious and immediate consequence of the theorems published by me three years ago, in the Transactions of the Royal Irish Academy... The indeterminate cases of my own theorems, which, optically interpreted, mean conical refraction, of course occurred to me at the time; but they had nothing to do with the subject of that paper; and the full examination of them... was reserved for a subsequent essay, which I expressed my intention of writing."[54] MacCullagh tempered these inflammatory remarks in a subsequent note to the *Philosophical Magazine*, but the incident did nothing to ease the tense relationship that would persist between Hamilton and MacCullagh.[55]

The theory of light was again in the pages of the *Philosophical Magazine* in 1845 and 1846; the heated discussion surrounding this topic was an example of controversy that incited Taylor to direct mathematical articles to other journals. Robert Moon, Fellow of Queen's College, Cambridge, dove into the debate when he criticized Fresnel's theory of double refraction:

> The most painful circumstance connected with the later history of the undulatory theory, is the manner in which ideas, in themselves perhaps valuable as hints, have been dressed up into a settled theory... Fresnel... was satisfied with a series of possibilities, upon which he has built a theory, not only of no value in itself, as having nothing solid to rest upon, but from its crudity and manifold errors discreditable to himself and to the age by which it has been received.[56]

---

[54] James MacCullagh, "Note on the Subject of Conical Refraction," *Philosophical Magazine*, 3rd ser. 3 (1833): 114-115 on p. 114. Spearman, "MacCullagh," p. 45.

[55] Spearman, "MacCullagh," p. 46. James MacCullagh, "Additional Note on Conical Refraction," *Philosophical Magazine*, 3rd ser., 3 (1833): 197-198.

[56] Robert Moon, "On Fresnel's Theory of Double Refraction," *Philosophical Magazine* 3rd ser., 27 (1845): 553-559 on p. 559.

Moon accompanied this biting criticism with an account of an illustration of the theory given earlier by the Astronomer Royal, Sir George Biddle Airy. After this account, Moon stated that "[w]hether the above illustration – for at best it would be nothing more – is due to Fresnel or Mr. Airy himself, I am not aware: but the whole is erroneous from beginning to end."[57] Apparently, only the editorial hand of Taylor restrained Moon from an even more aggressive attack of Airy in the above criticism. Moon complained to Taylor about the editor's alterations to his statement, saying that "[h]ad you felt unwilling to commit your journal to so strong an expression of opinion against Mr. Airy it would have been easy by a short editorial paragraph to have thrown the responsibility upon me or you might have declined to insert the article in its then form and I should have withdrawn it entirely."[58] Taylor replied that "I cannot pretend to exercise any judgement on the subject, discussed by you & those whom you oppose; but my office places on one the responsibility of watching over the tone & temper in which discussions are conducted... [Moon's original statement] seemed rather personal, uncourteous, & disparaging, – as well as wholly unconnected with your argument."[59]

Even in its less acidic, edited form, Moon's article induced more strong statements in the *Philosophical Magazine*. In an anonymous article that preceded the 1846 editorial notice, the author presents a calculation made by Moon in his account of

[57]*Ibid.*, p. 558.
[58]Robert Moon to Richard Taylor, Taylor & Francis Papers, St. Brides Library, London, 9 Dec. 1845.
[59]Richard Taylor to Robert Moon, Taylor & Francis Papers, St. Brides Library, London, 16 Dec. 1845.

Airy's demonstration and asks, "[d]oes Mr. Moon know anything of analysis? He was Eighth Wrangler in 1838, and therefore he ought to know something. His knowledge, however, has served him miserably on this occasion."[60]

Despite its policy of minimizing the publication of mathematics, the *Philosophical Magazine* became home to a growing share of mathematical articles during the middle third of the nineteenth century (see Table 3A). This growth in mathematical articles in the midst of editorial criticism seems even more surprising in light of the fact that the years from 1837 to 1867 coincide with the establishment of British journals devoted exclusively to publishing mathematical research.[61] As Helena Nešetřilová notes in her study of the journal from 1800 to 1850, "the number of mathematical articles also grew towards the end of the period described here, when specialized mathematical journals existed in England, while the content of the P[hilosophical] M[agazine] was multi-disciplined."[62] This phenomenon may be explained in part by Taylor's other journalistic ventures. As Brock and Meadows observe, "[t]he siphoning off of papers on biology and chemistry from the *Philosophical Magazine* into the *Annals* and the *Chemical Gazette* inevitably left the former journal with a pool of papers on mathematical and experimental physics."[63] As Table 3A shows, articles on the applied topics of mathematical physics, mechanics, geodesy, and astronomy

[60]Jesuiticus, "Remarks on a Paper by Mr. Moon on Fresnel's Theory of Double Refraction," *Philosophical Magazine* 3rd ser., 28 (1846): 144-145 on p. 145.

[61]In particular the *Cambridge Mathematical Journal* began in 1837 and continued, in two different incarnations, into the twentieth century. For more on this journal, see chapter 4.

[62]Nešetřilová, p. 96. We thank Helena Durnova for this translation. "Je zajímavé, že počet matematických článků vzrůstal i ke konci sledovaného období, kdy v Anglii již existovaly specializované matematické časopisy, přičemž PM byl časopis víceoborový."

[63]Brock and Meadows, p. 122.

dominated the mathematical content of the *Philosophical Magazine* for the entire nineteenth century; however, pure mathematical articles on algebra, analytic geometry, and differential and integral calculus also accounted for a substantial number of these pages.[64]

Although mathematics helped fill space caused by journal specialization at Taylor & Francis, the editors of the *Philosophical Magazine* still remained tentative about their coverage of mathematics. In 1864, Stokes, writing as a Secretary of the Royal Society of London, recommended to William Francis a paper by Archdeacon John Henry Pratt that represented "a resumé of the author's views in their most matured state."[65] This paper, which contained "extremely elaborate numerical calculations carefully checked," was rejected by the Royal Society referees but advocated by the Astronomer Royal to be printed in the *Philosophical Magazine.*[66] In a draft of his reply to Stokes, Francis wrote, "I fear the expense of printing Archdeacon Pratt's elaborate numerical calculations would prevent the Editors of the Phil. Mag. from accepting the paper for insertion in their journal; the more so as very many of the readers complain of having so many mathematical papers."[67]

Recommendations for the publication in the *Philosophical Magazine* of mathematical articles occurred in the absence of an articulated refereeing system for the

[64]These pure and applied mathematical areas also made a strong showing in a wider sample of nineteenth-century British journals. See chapter 7.

[65]Stokes to William Francis, Taylor & Francis Papers, St. Brides Library, London, 21 April 1864.

[66]*Ibid.*

[67]William Francis to Stokes, Taylor & Francis Papers, St. Brides Library, London, 21 April 1864. In this draft, Francis crossed out the even stronger sentiments: "there being too many of mathematical papers in it already," and "readers complain of having too many mathematical papers."

journal. In these circumstances, "decisions on whether or not to accept papers were presumably based solely on the judgement of the editor, who no doubt used his knowledge of the perceived standing of the contributor in scientific circles when making his selection."[68] In a note accompanying a paper for the *Philosophical Magazine*, lawyer and frequent mathematical contributor, James Cockle, took for granted that his work would be published: "[a]n old correspondent of the Philosophical Magazine, I have the pleasure of sending you for insertion (with your permission) in that Journal the little paper which will accompany this note. Will you kindly allow a 'proof' to be sent to my chambers?"[69] Charles Merrifield, principal of the Royal School of Naval Architecture in London, relied on a friend's, rather than his own, reputation to catch the eyes of the editors of the *Philosophical Magazine*, writing that "[i]t has been suggested to me by my friend Mr. Spottiswoode that the accompanying paper might suit the *Philosophical Magazine*."[70]

Other mathematical contributors to the journal pressed the editors to publish their material with speed in order to gain priority or exposure at the right moment. James Booth, Trinity College, Dublin graduate and principal of Bristol College, wrote Taylor that "I feel the more anxious that it [his paper] should appear as soon as possible as I am apprehensive of antecedent published discovery by some of the Continen-

[68] "Introduction: Science in the First Half of the Nineteenth Century," in *Science in the Making: Scientific Development as Chronicled by the Historic Papers in the Philosophical Magazine*, 2 vols., ed. E.A. Davis (London: Taylor & Francis, 1997), 1: xxxi-xxxiii on p. xxxii.

[69] James Cockle to William Francis, Taylor & Francis Papers, St. Brides Library, London, 1 Nov. 1852.

[70] Charles Merrifield to the editors of the *Philosophical Magazine*, Taylor & Francis Papers, St. Brides Library, London, 5 May 1868.

tal Mathematicians who have turned their attention to those subjects."[71] Similarly, William Spottiswoode, newly graduated in 1845 from Oxford, asked Taylor to print his paper on quaternions "in an Early Number; for the method of interpretation to wh.[ich] Professor [William Fishburn] Donkin [, Professor of Astronomy at Oxford] & myself have been led are the same, & the processes (which are independent) may illustrate & throw light upon one another."[72]

For the last third of the nineteenth century, the mathematical articles submitted to the *Philosophical Magazine* took on an increasingly applied character; in fact, for 1868 to 1900, mathematical physics alone claimed over 67% of the mathematical pages of the *Philosophical Magazine*, and articles on mechanics, geodesy, and astronomy accounted for over 17%. This trend reflected the general direction the *Magazine* was taking. By one estimate, 80-90% of the journal's contents for the second half of the nineteenth century have been categorized as physical.[73] However, several leading contributors of pure mathematical articles to the *Philosophical Magazine* at mid-century continued to contribute to the journal well into the 1880s. Sylvester, who made over 90 contributions to the *Philosophical Magazine*, submitted almost one-tenth of them

[71]James Booth to Richard Taylor, Taylor & Francis Papers, St. Brides Library, London, 19 Nov. 1840.

[72]William Spottiswoode to Richard Taylor, Taylor & Francis Papers, St. Brides Library, London, 3 July 1850.

[73]William H. Brock, "Foreword," in *Science in the Making*, 2: vii-xiii on p. xii. As Brock notes, "[t]he dividing line between mathematics and physics was then [in the nineteenth century] much hazier." (p. viii.) Thus, the articles that Brock counted as physical could have also been counted in Table 7A as mathematical physics. Besides the *Philosophical Magazine*, the mathematical articles published in nineteenth-century British scientific journals in general were dominated by applied mathematics. The percentage of applied mathematical pages in the *Philosophical Magazine* for 1868 to 1900, however, far outweighed that of all the journals considered together for this period. See chapter 7, especially tables 7B and 7C.

after 1870. James Cockle, an active pure mathematical contributor during the 1840s, made his last contribution in 1887. Besides established authors, in the late 1890s, the young American mathematician, George Abram Miller, published several articles to the *Philosophical Magazine* on substitution groups.[74] Pure mathematical textbooks and treatises were also reviewed in the *Philosophical Magazine* throughout the last half of the nineteenth century. However, by century's end, the *Philosophical Magazine* had evolved into a physics journal. Following and adapting to the trends of scientific periodical publishing as it had for decades, Taylor & Francis reshaped the *Philosophical Magazine* as a specialized periodical.

Of the numerous commercial scientific journals of nineteenth-century Britain, the *Philosophical Magazine* represents a notable example. Besides spanning the entire nineteenth century, this journal belongs to a group of only about 12 independent nineteenth-century British journals that continued to be published in the second half of the twentieth century.[75] Part of the journal's longevity could be attributed to the early consolidation of its ownership, editing, and publishing to one business. Thus, an investigation of the *Philosophical Magazine* and its owner, Taylor & Francis, provides insight into the necessary diplomacy of an editor, the business decisions of a journal proprietor, and the expenses and other factors intrinsic to printing and distributing a periodical. While navigating its business venture through the perilous waters of scientific journal production, Taylor & Francis also had to consider its mathematical constituency. By acting as contributors, translators, and informal referees, this group

[74]For more on Miller, see chapter 6.
[75]Brock, "Development," p. 96.

supported and tried to direct the mathematical contents of both the *Philosophical Magazine* and its cousin the *Scientific Memoirs.* While vying for room with writers from a multitude of disciplines or just from physics, mathematicians used the *Philosophical Magazine* as a publication outlet throughout the nineteenth century.

The Mathematics of *Nature*: 1869-1900

British mathematicians, while supportive of the *Philosophical Magazine* throughout the nineteenth century, were also among the group of scientists interested and involved in the establishment and progression of the journal *Nature.* James Joseph Sylvester, Professor of Mathematics at the Royal Military Academy at Woolwich, overflowed with excitement for the new venture when he wrote to the journal's editor:

> What a glorious title, Nature — a veritable stroke of genius to have hit upon. It is more than Cosmos, more than Universe. It includes the seen as well as the unseen, the possible as well as the actual, Nature and Nature's God, mind and matter. I am lost in admiration of the effulgent blaze of ideas it calls forth.[76]

Begun in 1869, *Nature* was a manifestation of the contemporary realization "that science was an important and expanding area of human activity, yet one that was growing beyond the average man's understanding."[77] As older general science journals like the *Philosophical Magazine* became increasingly specialized, they left in their

[76]Sylvester to Norman Lockyer, 15 Oct 1869, in Arthur Jack Meadows, *Science and Controversy: A Biography of Sir Norman Lockyer* (Cambridge, MA: MIT Press, 1972), p. 26. Sylvester had considerable journalistic experience as co-editor of the *Quarterly Journal of Pure and Applied Mathematics* and earlier as a regular scientific contributor to one of *Nature*'s predecessors, the *Saturday Review.* Roy M. Macleod, "Science in Grub Street," *Nature* 224 (1969): 423-427 on pp. 425-426.

[77]Arthur Jack Meadows, "Access to the Results of Scientific Research: Developments in Victorian Britain," in *Development of Science Publishing in Europe*, pp. 43-62 on p. 54.

wakes a need for interdisciplinary communication. Norman Lockyer, scientific advisor to the Macmillan publishing company, recognized this need and convinced his friend and employer, Alexander Macmillan, to produce the new journal. Lockyer had secured his scientific reputation the year before *Nature*'s establishment with his spectroscopic discovery of helium and a fellowship in the Royal Society, and he had established his journalistic reputation as the science editor of *The Reader: A Review of Current Literature* from its foundation in 1863 to 1866.[78] As *Nature*'s first editor, Lockyer set the journal's objectives as "the announcement of fresh results, the public promotion of science, the diffusion of scientific information and the airing of controversy. Part professional and research; part educational and amateur."[79] The new journal was assembled each week by Lockyer and a "private army of sub-editors" trained scientifically and journalistically,[80] and it quickly assumed a role as "the favourite god-child of the scientific community."[81] British mathematicians supplied Lockyer with a variety of mathematical articles and used *Nature* as a vehicle for quickly disseminating the news and opinions of their developing community.

Through a sample of each year's issues of *Nature* from 1869 to 1900,[82] we can see

[78]Roy M. MacLeod, "Seeds of Competition," *Nature* 244 (1969): 431-434 on 431; and "The New Journal," *Nature* 224 (1969): 437-439 on p. 438. In its death notice of Macmillan in 1896, *Nature* stated that "outside the field of scientific workers there were few who possessed a greater sympathy with scientific aims, few who had a keener insight as to the place science should occupy in our national life and in our educational systems." "Death of Mr. Alexander Macmillan," *Nature* 53 (1896): 302.

[79]Roy M. Macleod, "The First Issue," *Nature* 224 (1969): 440.

[80]Roy M. Macleod, "Private Army of Contributors," *Nature* 224 (1969): 445-449 on p. 445.

[81]Roy M. Macleod, "Securing the Foundations," *Nature* 224 (1969): 441-444 on p. 442.

[82]This table is based on 480 issues of *Nature*. For each year (1869-1900), 15 issues were randomly sampled from the 52 issues published in that year. The sample used a discrete uniform distribution to select the issues for each year.

that mathematics and mathematically related news appeared in a variety of forms (see Table 3B). One weekly department, the letters to the editor, provided mathematicians a forum in which to argue for educational reform, to appeal for help, and to air disputes. In *Nature*'s first volume, the issues that ultimately motivated the creation of the Association for the Improvement of Geometrical Teaching (AIGT) appeared in a letter by Robert Tucker, Secretary of the London Mathematical Society. He advocated examinations that would test aspects of the "modern views" of geometry, rather than the established examinations that tested a knowledge of Euclid: "[e]very examining body, if a fair field is to be given to the students of modern geometry, should put forth a [revised examination] scheme...and not merely put it forth 'as a sop to Cerberus,' but act upon it and let it be a reality."[83] In the next volume of *Nature*, Rawdon Levett, a teacher at King Edward's School in Birmingham, called for an "Anti-Euclid Association."[84] Soon after these calls to action by Tucker, Levett, and others, *Nature* announced a conference to consider the formation of the Association for the Reform of Geometrical Teaching.[85] It was through this that the initial goals of the AIGT were decided.[86]

Besides educational issues, mathematicians used *Nature*'s correspondence section to address mathematicians efficiently. Robert Tucker, for example, requested help in 1879 in compiling the mathematical papers of William Kingdon Clifford. Having agreed to edit the memoirs of Clifford, who had died at the age of 33 in March of

---

[83]Robert Tucker, "Euclid as a Text-Book," *Nature* 1 (1870): 534.
[84]Rawdon Levett, "Euclid as a Text-Book," *Nature* 2 (1870): 65-66 on p. 65.
[85]"Association for the Reform of Geometrical Teaching," *Nature* 3 (1870): 169.
[86]"Notes," *Nature* 106 (1921): 638-639.

Table 3B: Mathematical Contributions to Sample Issues[†] of *Nature*, 1869-1900

		V. 1-10 (1869-1874)	V. 11-20 (1874-1879)	V. 21-30 (1879-1884)	V. 31-40 (1884-1889)	V.41-50 (1889-1894)	V. 51-62 (1896-1900)	**Total**
Book Reviews	#	8	23	15	35	35	37	**153**
	Pages[‡]	4.4	13.9	6.8	19.2	19.3	21.4	**84.9**
Letters to the Editor	#	24	11	9	14	22	19	**99**
	Pages	10.4	4.8	2.1	5.4	10.0	10.6	**43.2**
Sci. Society Reports[¶]	#	13	18	16	11	11	20	**89**
	Pages	14.8	16.0	3.0	7.5	4.4	12.2	**57.9**
Journal Reviews	#	0	5	2	3	9	18	**37**
	Pages	0.0	2.3	0.9	1.0	1.7	4.1	**9.9**
Leading Articles	#	4	4	1	8	5	7	**29**
	Pages	7.1	9.8	2.6	16.1	8.5	13.3	**57.4**
Original Articles*	#	2	4	7	7	4	1	**25**
	Pages	1	14.4	11.0	8.9	9.8	4.3	**49.3**
Reprinted Articles	#	1	3	1	4	9	4	**22**
	Pages	1.1	7.5	1.5	7.7	18.5	7.6	**43.9**
Obits. [§]	#	2	0	3	2	2	6	**15**
	Pages	3.5	0.0	4.0	1.5	1.4	5.3	**15.7**
Total Number of Articles		**54**	**68**	**54**	**84**	**97**	**112**	**469**
Total Math'l Pages/ Pages in Sample Issues		**42.2/ 1502**	**68.5/ 1705**	**31.9/ 1805**	**67.3/ 1823**	**73.5/ 1992**	**78.7/ 2172**	**362.0/ 10,999**
Percentage of Total Math'l Pages to Pages in Sample Issues		**2.8%**	**3.9%**	**1.8%**	**3.7%**	**3.7%**	**3.6%**	**3.3%**

[†] This table is based on 480 issues of *Nature.* For each year (1869-1900), 15 issues were randomly sampled from the 52 issues published in that year (two volumes covered from November of one year to October of the next. Thus we define a year in those terms). The sample used a discrete uniform distribution to select the issues for each year.

[‡] Page lengths were estimated by the proportion of the page(s) that each article occupied. Because of rounding errors, the page lengths for each period may not sum exactly to the total.

[¶] This category consists of the mathematics found in *Nature*'s reports of meetings of the British Association for the Advancement of Science (which had a separate Mathematics and Physical Sciences Section A), the Edinburgh Mathematical Society, and the London Mathematical Society. Mathematics found in *Nature*'s reports of general scientific society such as the Royal Society of London or the French Academy of Sciences is not considered here. The large differences in page lengths for each five-year period can be attributed to the very short length of the accounts of the London Mathematical Society

* Original articles consist of those which do not belong to any of the other categories above.

[§] This category does not include the notices of deaths found in *Nature*'s "Notes" section.

1879, Tucker sought to "secure the co-operation of all mathematicians who are interested in the matter."[87] He listed the works by Clifford he had found in the late mathematician's personal collection, offered to distribute the extra copies from this collection "to mathematicians who may wish to have them,"[88] and issued an appeal for any of Clifford's papers he had not yet found.

Writing in 1885 as the editor of the recently departed Issac Todhunter's unfinished *History of the Mathematical Theories of Elasticity*, Karl Pearson also authored a letter to the editor of *Nature* in which he asked his fellow mathematicians for help. Pearson, Professor of Applied Mathematics and mechanics at University College, London, recognized a "looseness" in the meanings of terms in elasticity and appealed for "any suggestions, through the columns of NATURE, towards a definite and uniform terminology."[89] Pearson's request was answered less than a month later by Alexander B.W. Kennedy, Professor of Engineering and Mechanical Technology and also at University College, London.[90] While these two correspondents worked at the same institution, they informed each other through *Nature*.

As a British mathematician who worked hard to establish an international reputation,[91] Sylvester regarded the correspondence section of *Nature* as an outlet through

[87]Robert Tucker, "Prof. Clifford's Mathematical Papers," *Nature* 20 (1879): 195.

[88]*Ibid.*

[89]Karl Pearson, "On the Terminology of the Mathematical Theory of Elasticity," *Nature* 31 (1885): 456-457 on p. 457. Todhunter, a well-known writer of textbooks, had died on 1 March 1884. Pearson, along with Francis Galton, and Walter F.R. Weldon, established the statistical journal *Biometrika* in 1899.

[90]Alexander B.W. Kennedy, "On the Terminology of the Mathematical Theory of Elasticity," *Nature* 31 (1885): 304-305.

[91]See Karen Hunger Parshall and Eugene Seneta, "Building an International Reputation: The Case of J.J. Sylvester (1814-1897)," *American Mathematical Monthly* 104 (1997): 210-222 on p. 215.

which to defend himself against a criticism of his *Philosophical Transactions* memoir, "On the Motion of a Rigid Body Acted on by no External Forces,"[92] made by the Paris mathematician, Jean Charles Rodolphe Radau. Sylvester, in *Nature*'s first volume, outlined Radau's objections and feverishly stated that "[i]t is, indeed, surprising that such a perversion of the facts of the case should have found insertion in a serious journal, such as that published by the Ecole Normale Supérieure, and I might fairly have expected from M. Radau the courtesy habitual with his adopted[93] countrymen, of applying to me for information on anything in my paper which might have appeared to him obscure or erroneous, before rushing into print with such a *mare's nest.*"[94] Two weeks later, Sylvester reported in another letter that his earlier note in *Nature* won him the notice and apology of Radau: " 'One touch of *Nature* makes the whole world kin.' In a note addressed to me full of true dignity, this gentleman has made much more than sufficient reparation for his previous trifling act of inadvertence...I, on my part, deeply lament the unnecessary tone of acerbity in which my reference to this criticism was couched."[95] He went on to describe a contested issue in his earlier memoir, the method by which an ellipsoid can be made to roll while fixing its center. After only a few paragraphs of general detail, Sylvester ended his article with the comment, "I fear that NATURE, used to a more succulent diet, has had as much as it

[92]J.J. Sylvester "On the Motion of a Rigid Body Acted on by No External Forces," *Philosophical Transactions of the Royal Society of London* 156 (1866): 757-780; also in *The Collected Mathematical Papers of James Joseph Sylvester*, ed. Henry Frederick Baker, 4 vols (Cambridge: University Press, 1904; reprint ed., New York: Chelsea Publishing Co., 1973), 2: 577-601.

[93]Radau was born and studied in Prussia before moving to Paris in 1858. *Poggendorff*, s.v., "Radau, Jean Charles Rodolphe."

[94]J.J. Sylvester, "The Motion of a Free Rotating Body," *Nature* 1 (1870): 482. Sylvester's emphasis.

[95]J.J. Sylvester, "Rotation of a Rigid Body," *Nature* 1 (1870): 532.

can bear upon so dry a topic, and, although having more to say I deem it wiser to bring these remarks to an end."[96]

Sylvester's remark reflects the attitude that *Nature* was a useful source for news, correspondence, and announcements, but not for deep mathematical discussion. In fact, the original mathematical articles found in this study's sample of *Nature* lack both the extensive form found in the *Philosophical Transactions*[97] and the detailed quality of articles found in the *Quarterly Journal for Pure and Applied Mathematics.* Instead, most of these articles were written with a wide scientific audience in mind, or they concerned the mathematical news items of book reviews, society notices, or current educational issues.

In his 1885 article, "Elliptic Space," Robert Ball described to *Nature*'s wide scientific audience an aspect of the projective interpretation of non-Euclidean geometry that had been vigorously pursued by him as well as by William Kingdon Clifford, Homersham Cox, and Arthur Buchheim since the late 1870s.[98] Ball informed his readers that "[t]he present little paper is intended to illustrate the unartificial character of the elliptic geometry and to indicate the analytical nature of the axiom which the Euclidean geometry requires us to introduce. We investigate the *measurement of distance* on which the theory of elliptic space chiefly depends."[99] By taking "hint[s]

[96] *Ibid.*

[97] The longest original article in this sample occupied only a little over five pages of text in *Nature.*

[98] Joan L. Richards, *Mathematical Visions: The Pursuit of Geometry in Victorian England* (Boston: Academic Press, 1988), p. 143. In 1879, Ball gave an earlier popular presentation of non-Euclidean geometry. Robert S. Ball, "The Non-Euclidean Geometry," *Hermathena* 3 (1877-1879): 500-541. Ball would express doubts about the projective approach to non-Euclidean geometry in 1887. See Richards, pp. 216-217.

[99] Robert Ball, "Elliptic Space," *Nature* 33 (1885): 86-87 on p. 86. Ball's emphasis.

from our familiar geometry," Ball led his reader to a logarithmic formulation of distance.[100] Cayley had applied this conception of distance to projective geometry in his 1859 "Sixth Memoir on Quantics;" 12 years later, this conception was further developed by Felix Klein who utilized it in his interpretation of non-Euclidean geometry. Ball's "little paper" in *Nature* gave general readers an idea of a developing trend in the British approach to a young mathematical area.[101]

Besides original mathematical contributions, *Nature* also reprinted works of general mathematical interest. For example, this study's sample included reprinted addresses made before the London Mathematical Society, the New York Mathematical Society, the Association for the Improvement of Geometrical Teaching, the Royal Institution, the Royal Society of London, the Royal Society of Edinburgh, and the British Association.[102] Foreign mathematical works were also reprinted in translation. Clifford translated Bernhard Riemann's "On the Hypotheses Which Lie at the Bases of Geometry" in 1873,[103] and Alfred Greenhill translated "Mathematics of the

[100] *Ibid.*, p. 87.

[101] In 1884, a year before Ball's article appeared in *Nature*, Edwin Abbott Abbott published his popular book *Flatland*, in which the narrator, "A Square," describes his two-dimensional world to the reader and tries to explain the three-dimensional world to his fellow citizens. Similarly, 14 years earlier in an article in *The Academy*, Hermann Helmholtz introduced ideas about non-Euclidean geometry to British readers by describing a hollow sphere inhabited by flat objects capable of human reason. This article was sharply criticized in 1871 by University College London economics Professor, William Stanley Jevons, in a leader in *Nature*. However, Richards points out that by "the mid-1870s non-Euclidean ideas were readily available in England." Richards, p. 74. Edward Abbott Abbott, *Flatland: A Romance of Many Dimensions*, (1884; reprint ed., Princeton: University Press, 1991); Hermann Helmholtz, "Science and Philosophy," *The Academy* 1 (1870): 128-131; and William Stanley Jevons, "Helmholtz on the Axioms of Geometry," *Nature* 6 (1871): 481-482.

[102] These addresses included James W. L. Glaisher, "The Mathematical Tripos," *Nature* 35 (1886): 199-203; Horace Lamb, "On the Deformation of an Elastic Shell," *Nature* 41 (1890): 549; and Simon Newcomb, "Modern Mathematical Thought," *Nature* 49 (1894): 325-329.

[103] Bernhard Riemann, "On the Hypotheses Which Lie at the Bases of Geometry," trans. William Kingdon Clifford *Nature* 8(1873): 14-17, 36-37. Riemann presented this memoir as his *Habilitationsvortrag* in 1854. It was published in 1866 in the thirteenth volume of *Abhandlungen der*

Spinning Top" by Felix Klein and Arnold Sommerfeld in 1899;[104] in 1890, *Nature* also presented in English a retrospective that Charles Hermite had given of mathematical teaching at the Sorbonne.[105]

More than correspondence, original articles or reprinted works, book reviews put mathematics on the pages of *Nature*. These reviews were not merely summaries of works; they sometimes contained strong opinions by those who wanted to uphold a high set of standards for mathematics. For example, in his commentary on A. Drayson's *Proper Motion of the Fixed Stars*, the reviewer pointed out that *Nature* had made notice of an earlier work by Drayson that "was founded on misconception and ignorance, and in this respect the [current] one may fairly be called a sequel to the other... His geometry, it is true, is a much more powerful instrument than anything of the same name which we have had the fortune to meet with so far."[106] The reviewer who evaluated *La Théorie Hugodécimale* by Léopold Hugo was similarly critical; Hugo had boasted in the forward to his pamphlet, "Crush the ... [routine mathematicians]! Let them tremble, cowered through their small science, before the hugomatical hurricane!"[107] After noting the negative review of Hugo's work by Camille Gérono in the

Königlichen Gesellschaft der Wissenschaften zu Göttingen. According to Jeremy Gray, "[f]or the first time it becomes possible [with Riemann's work] to think geometrically in terms more basic than those of Euclid, with the result that ambiguities and difficulties in Euclid's formulation can be resolved... Further, it became possible to design geometries that were highly non-Euclidean, lacking many properties of Euclid's but having new ones of their own." Jeremy Gray, *Ideas of Space: Euclidean Non-Euclidean and Relativistic* (Oxford: Clarendon Press, 1989), p.141. Clifford, described by Richards as "the major English spokesman for Riemann's ideas," also gave a series of lectures of a popular nature on Riemann's concepts at the Royal Institution in 1874. Richards, p. 69, 92.

[104]Felix Klein and Arnold Sommerfeld, "Mathematics of the Spinning Top," trans. Alfred George Greenhill, *Nature* 60 (1899): 319-322, 346-349.

[105]Charles Hermite, "Mathematical Teaching at the Sorbonne 1809-1889," *Nature* 41 (1890): 597-598.

[106]"Drayson's 'Proper Motion of the Fixed Stars,' etc.," *Nature* 11 (1874): 66-67 on p. 66.

[107]Léopold Hugo, quoted in "*La Théorie Hugodécimale; ou, La Base scientifique et définitive de*

Nouvelles annales de mathématiques, the reviewer sarcastically remarked that "the writings of such a visionary [Hugo] perhaps hardly merit a notice; we are disposed henceforth to let him go his own way, trusting that time will clear up many, if not all, of his crochets."[108]

Positive reviews of an emerging group of mathematicians also appeared in *Nature.* The mathematical work of Americans received notice in the *Nature*'s journal reviews; in fact, the sharp rise in the number of journal reviews in this study's sample during the 1890s can be largely attributed to notices of the *American Journal of Mathematics* and the *Bulletin of the American Mathematical Society.*[109] A review of several volumes of the *American Journal of Mathematics* also appeared as a leading article to an 1885 issue of *Nature.* This overview evaluated volumes of the journal that had appeared after its first editor, J.J. Sylvester, had returned to England. The anonymous reviewer remarked that "[s]ome readers might like to have a more diversified bill of fare set before them, but no one can say that what is offered is not generally first class...We are glad to find this young work maintaining its early promise, and we wish for it even higher success in the days to come."[110]

Reviews of new works also often appeared in *Nature*'s mathematical leaders.[111]

---

l'Arithmologistique universelle. Par le Cte. Léopold Hugo (Paris 1877)," *Nature* 16 (1877): 359. "Écrasons les pan-routiniers! qu'ils tremblent, blottis dans leur petite science, devant l'ouragon hugomatique!"

[108] "*La Théorie Hugodécimale,*" p. 359.

[109] Of the 26 journal reviews of this study's sample from the 1890s, 12 were of the *American Journal of Mathematics*, nine were of the *Bulletin of the American Mathematical Society*, and four were of the *Bulletin* of the AMS's predecessor, the New York Mathematical Society.

[110] "The 'American Journal of Mathematics'," *Nature* 31 (1885): 189-190 on p. 190.

[111] In his analysis of the chief leader writers for *Nature* (i.e., those who authored more than five leading articles), Roy Macleod places ten of the 85 members of this group from 1869 to 1899 in the fields of astronomy or mathematics. This group of 85 chief leader writers wrote 40% of the leaders

In general, these reviews appearing as the leading article of an issue occupied more column space and contained more detail than those found in *Nature*'s "Our Book Shelf" department. They also allowed the reviewer to veer somewhat from his task and comment on the state of British mathematics. William Burnside, a pioneer in the theory of groups and Professor of Mathematics at the Royal Naval College in Greenwich, chose to comment on the "curiously restricted" pure mathematical curriculum in England while reviewing Andrew Forsyth's *Theory of Functions of a Complex Variable*:

> At Cambridge, and probably to a great extent in other centres, the teaching and the course of study of individual students have tended on the whole to follow the lines of the available English text-books, and where these have been incomplete or entirely wanting there has, till very recent years, been no sufficient introduction to the corresponding subjects. Why a subject of such fundamental importance for the advancement of pure mathematics as the theory of functions should have happened to fall into this latter class, it is not easy to tell.[112]

While reviewing University of Edinburgh professors Phillip Kelland and Peter Guthrie Tait's *Introduction to Quaternions, with Numerous Examples*, the anonymous[113] re-

during 1869-1879, 49.4% for the 1880s, and 51% for the 1890s. Among these, Alfred Greenhill, Professor of Mathematics at the Royal Military Academy at Woolwich, was listed as one of the most prolific leader writers for the 1890s. Described as "known to the readers of NATURE as a friend militant of the practical man," and as the "mathematical friend" of the "practical man," Greenhill also received notice in the academic world. He graduated Second Wrangler and Smith's Prizeman from St. John's College, Cambridge in 1870, became a fellow of the Royal Society of London in 1888, won the De Morgan Medal from the London Mathematical Society in 1902, was knighted six years later, and became a corresponding member of the Paris Académie des Sciences in 1921. See Macleod, "Private Army of Contributors," p. 449; [Anonymous], "Greenhill's Differential and Integral Calculus," *Nature* 44 (1891): 170-172; and John Venn, *Alumni Cantabrigienses; A Biographical List of All Known Students, Graduates and Holders of Office at the University of Cambridge* (Cambridge: University Press, 1922-54) s.v. "Greenhill, George Alfred."

[112]William Burnside, "The Theory of Functions," *Nature* 48 (1893): 169-170 on p. 169. For more on function theory in nineteenth-century Britain, see chapter 7.

[113]As the examples above illustrate, reviewers could choose to be anonymous or named in their articles to *Nature*. Macleod pointed out that "[f]airly early on, Lockyer decided that the problem of 'free and just' criticism was more a matter of personality than principle and the choice of signature or anonymity was left to his authors." Macleod, "Private Army of Contributors," p. 448.

viewer mused on the purposes and methods of the mathematician:

> [T]he methods on which the mathematician is content to hang his reputation are generally those which he fancies will save him and all who come after him the labour of thinking about what has cost himself so much thought. Now Quaternions, ... is a method of thinking, and not, at least for the present generation, a method of saving thought... Two courses, however, are open to the cultivators of Quaternions: they may show how easily the principles of the method are acquired by those whose minds are still fresh, and in so doing they may prepare the way for the triumph of Quaternions in the next generation; or they may apply the method to those problems which the science of the day presents to us, and show how easily it arrives at those solutions which have been already expressed in ordinary mathematical language, and how it brings within our reach other problems, which the ordinary methods have hitherto abstained from attacking.[114]

In writing book reviews for *Nature*'s leaders, British mathematicians had the opportunity to review both books and the state of their discipline.

Mathematicians also appeared in a series of leaders in *Nature* called "Scientific Worthies." This feature presented the biographies and results of applied and pure mathematicians including Stokes, Sir William Thomson, Hermann Helmholtz, Spottiswoode, Sylvester, and Cayley.[115] The lives of both foreign and domestic mathematicians also received notice in *Nature*'s obituaries.

While leading articles formed the most noticeable platform for mathematics in *Nature*, the journal reported the work of British mathematicians more regularly in its reports of mathematical society meetings. These reports gave succinct statements of the mathematical results presented at the meetings of the London Mathematical Society, Edinburgh Mathematical Society, and the Mathematical and Physical Sciences

[114] "Quaternions," *Nature* 9 (1873): 137-138.
[115] "Advertisement: Scientific Worthies," *Nature* 33 (1886): xxxiv.

Section (A) of the British Association for the Advancement of Science.[116] MacLeod described *Nature*'s editorial staff as Lockyer's " 'eyes and ears' in the councils of scientific societies everywhere."[117] In fact, before serving as President of the London Mathematical Society from 1890 to 1892, *Nature* mathematical writer, Alfred Greenhill, served on the Society's Council for many years.[118]

As this study's sample has shown, mathematical articles appeared in every department of *Nature*. While the number of mathematical articles grew steadily from 1886 to 1900, the size of *Nature*'s volumes also grew. The percentage of pages in sample issues that concern mathematics remained generally steady throughout the century (see Table 3B). Thus, the nineteenth-century mathematical articles maintained a stable but far from overwhelming presence in *Nature*'s columns.

In the first volume of *Nature*, Lockyer had outlined the goals he hoped his journal would fulfill:

> FIRST, to place before the general public the grand results of Scientific Work and Scientific Discovery, and to urge the claims of Science to a more general recognition in Education and in Daily Life; And, SECONDLY, to aid Scientific men themselves, by giving early information of all advances made in any branch of Natural knowledge throughout the world and by affording them an opportunity of discussing the various Scientific questions which arise from time to time.[119]

[116] *Nature*'s society section also recorded British mathematical activity in general scientific societies such as the Royal Society, the Royal Irish Academy, the Cambridge Philosophical Society, the Manchester Literary and Philosophical Society, as well as the Royal Society of New South Wales, and the Académie des Sciences. However, since the mathematical proceedings were mixed in with reports of other scientific reports of these societies, they were not included in this study's statistics.

[117] MacLeod, "Private Army of Contributors," p. 446.

[118] Augustus E.H. Love, "Alfred George Greenhill," *Journal of the London Mathematical Society* 3 (1928): 27-32 on p. 27. Greenhill also served on the Royal Society Council from 1896 to 1897. Interestingly, in this study's sample of *Nature*, the average length for the notices of the London Mathematical Society was about one third of a page; however, the longest notice of the LMS, which was 1.25 pages long, contained a notice of Greenhill's work.

[119] [Preface], *Nature* 1 (20 January 1870).

From its inception, *Nature* struggled with its objective of presenting results to the general public,[120] a problem that especially applied to mathematics. However, issues of mathematics education that were raised in *Nature*'s letters to the editor as well as its reviews of mathematical textbooks did at least expose educators and scientists, if not the general public, to issues important to the future of mathematics. *Nature*'s mathematical articles more clearly achieved Lockyer's second objective. Mathematicians took advantage of the journal's weekly format both to communicate and to learn news of emerging results, texts, and issues. While it did not provide a forum for the full presentation of mathematical findings, *Nature* did furnish efficient lines of communication to the nineteenth-century British mathematical publication community.

Independent "Minor Mathematical Serials"

The support of the *Philosophical Magazine* and *Nature* from British mathematicians indicates that independent general science journals played a significant role in mathematical interaction throughout the nineteenth century. While these journals filled needs of speedy publication and interdisciplinary communication left unsatisfied by the publications of the scientific societies, there remained room in the mathematical publication spectrum for other genres of journals. Commercial journals devoted to specific disciplines represented a considerable portion of specialized periodicals by the nineteenth century, and mathematics was no exception.[121] Mathematics also

[120]Meadows, *Science and Controversy*, pp. 28-29

[121]Commercial journals (for all countries for 1665 to 1900) represented a considerable portion of the periodicals devoted to botany (51%), experimental biology (56%), mathematics (35%), physics (69%), and chemistry (31%). Robert Mortimer Gascoigne, *A Historical Catalogue of Scientific Periodicals, 1665-1900* (New York: Garland Publishing, Inc., 1985), p. 136.

infiltrated commercial periodicals not exclusively devoted to mathematics that also concentrated on pursuits such as education, literature, or the entertainment of British ladies and gentlemen.

By 1808, Britain had a mathematical journalistic tradition that was over one century old. In the same year, University of Edinburgh Professor John Playfair described the periodicals that comprised this tradition:

> In these, many curious problems, not of the highest order indeed, but still having a considerable degree of difficulty, and far beyond the mere elements of science, are often to be met with; and the great number of ingenious men who take a share in proposing and answering these questions, whom one has never heard of any where else, is not a little surprising. Nothing of the same kind, we believe, is to be found in any other country.[122]

These serials, in Playfair's opinion, provided proof that "a certain degree of mathematical science, and indeed no inconsiderable degree, is perhaps more widely diffused in England, than in any other country of the world."[123] Over a century later, Raymond Archibald surveyed these journals as well as what he called the "minor mathematical serials" that they spawned.[124] This section considers the editors, financial struggles, style, and content of these periodicals and explores the extent to which this sort of publication encouraged the pursuit of mathematics in Britain.

Independent journals devoted to mathematics established a financial foothold in the eighteenth century by appealing to "philomaths."[125] Possibly the first British

[122][John Playfair], "[Review:] *Traité de Méchanique Céleste*," *Edinburgh Review* 11 (1808): 249-284 on p. 282.
[123]*Ibid.*
[124]Archibald.
[125]The term "philomaths" was used from the beginning of the seventeenth century to the beginning of the nineteenth century for those "who used mathematics in their trade or craft and appreciated

independent journal containing mathematics, the *Ladies' Diary*, was initially established in 1704 as an almanac with articles for homemakers, but, by 1707, it had replaced many of its domestic features with mathematical ones.[126] A typical issue of the *Ladies' Diary* contained:

> 48 pages, the first 16 contained a preface, usually unsigned; a list of eclipses for the year compiled by various contributors; and a calendar for the year with a diary of notable anniversaries and holy days, and the differences between dial and clock times. There followed 4 or 5 pages of solutions to the previous year's Aenigmas, 13 or 14 pages of solutions to the mathematical questions, 12 or 13 pages of new puzzles and questions, a page containing a summary list of contributors with the numbers of the questions they had solved, and a page of advertisements. The Aenigmas, or word puzzles, were proposed and answered in verse, and sometimes included one in Greek, Latin, or French. At first the mathematical questions were set in verse and answered partly in the same way. However, after 1730 some prose questions appeared, and by 1745 they predominated. The name of the solver of a problem was given at the head of the solution; at the end there often appeared the names of other solvers, sometimes as many as 30.[127]

The popularity of the journal's format sustained it for 136 years and inspired scores of similar journals throughout the eighteenth and nineteenth centuries (see Table 3C). While the problems presented in these journals were "not of the highest order," John Playfair asserted that they "have tended to awaken curiosity, and the solutions to convey instruction, in a much better manner than is always to be found in more splendid publications."[128] Thomas Kirkman[129] extolled similar virtues of the Ladies' Diary: "an incomparably greater share of the glory of kindling and cherishing

its power." Ruth Wallis and Peter Wallis, "Female Philomaths," *Historia Mathematica* 7 (1980): 57-64 on p. 59.

[126]Teri Perl, "The Ladies' Diary or Woman's Almanack, 1704-1841," *Historia Mathematica* 6 (1979): 36-53 on p. 37.

[127]Wallis and Wallis, p. 58.

[128]Playfair, p. 279.

[129]Recall from chapter 2 that Kirkman was a country rector and active mathematical author.

Table 3C: Minor Mathematical Serials Listed by Archibald[†]

a. Eighteenth-Century Mathematical Serials

Delights for the Ingenious	1711-1711	*Mathematical Transactions*	1762-1762
Miscellaneae Curiosae	1734-1735	*Miscellanea Scientifica Curiosa*	1766-1769
Supp. to the Gentleman's Diary	1743-1745	*British Oracle*	1769-1770
Miscellanea Curiosa Mathematica	1745-1753	*Town and Country Magazine*	1769-1792
Mathematician (Rollinson)	1745-1750	*Diarian Repository*	1771-1771
Newcastle General Magazine	1747-1757	*Diarian Miscellany*	1771-1775
Palladium	1749-1779	*Miscellanea Mathematica*	1771-1775
Mathematical Exercises	1750-1753	*London Magazine*	1774-1785
Gentleman's Magazine	1751-1768	*Carnan's Diary*	1776-1788
Ladies Philosopher	1752-1754	*Lady's and Gentleman's Scientifical Repository*	1783-1784
Ladies Chronologer	1754-1754	*Diaria Britannica*	1787-1795
Miscellaneous Correspondence	1755-1763	*Supp. to the Ladies Diary*	1788-1790
Gentleman and Lady's Military Palladium	1759-1759	*Math'l and Philosophical Repository (Davison)*	1789-1791
Imperial Magazine	1760-1762	*Mathematical, Geometrical and Philosophical Delights*	1792-1798
Mathematical Magazine	1761-1761	*Stockton Bee*	1793-1795
Court Magazine	1761-1765	*Yorkshire Repository*	1794-1795

b. Mathematical Serial Existing or Established in the Nineteenth Century

Ladies' Diary	1704-1840	*Liverpool Apollonius*	1823-1824
Gentleman's Diary (Davis)	1741-1814	*Scientific Receptacle (Clay)*	1825-1825
Gentleman's Diary	1741-1840	*Math'l Associate*	1827-1830
Scientific Receptacle (Whiting)	1791-1819	*Scientific Mirror*	1829-1830
Diary Companion	1792-1806	*York Courant- math'l column*	1829-1846
Math'l Repository (Leybourne)	1795-1835	*Private Tutor*	1830-1831
Student	1797-1800	*Northumbrian Mirror*	1837-1841
Gentleman's Math'l Companion	1797-1826	*Lady's and Gentleman's Diary*	1841-1871
Enquirer	1811-1813	*Mathematician (Davies)*	1843-1850
Quarterly Visitor	1813-1815	*Educational Times Math'l Column*	1847-1915
Leeds Correspondent	1814-1823	*Western Miscellany*	1849-1850
Newcastle Magazine	1820-1831	*Alnwick Journal*	1862-1863
Student's Companion	1822-1823	*Math'l Questions... From the "Educational Times"*	1864-1918

† Raymond Archibald, "Notes on Some Minor English Mathematical Serials," *Mathematical Gazette* 14 (1929): 379-400.

a pure and lasting love of mathematical science in men as well as boys, must be attributed to the immortal *Lady Dia*[ary], than to all the universities and colleges of these kingdoms put together, to all our Lyceums, Athenæums, and Philosophical Societies, and to all our Imperial Boards of peace and war."[130]

During the last half of the *Ladies' Diary*'s life (1773-1840), its editorship and much of its contributorship centered on the Royal Military College at Woolich. Charles Hutton and Olinthus Gregory served on the mathematics faculty at the college and as successive editors of the journal.[131] After educating himself outside of the university environment, Hutton began his mathematical career in 1764 by contributing to the *Ladies' Diary.*[132] He successfully competed for the professorship of mathematics at Woolwich in 1773 and began editing the *Diary* in the same year. As editor, "he encouraged many younger mathematicians and acted as a leader of the philomatic movement."[133] Olinthus Gregory, also educated outside of the university sphere and a *Ladies' Diary* contributor beginning in 1794, was deeply influenced by Hutton. With the editor's help, Gregory became second mathematical assistant at Woolwich in 1803; in 1821, he obtained the mathematical professorship.[134] In 1818, Hutton,

[130]Thomas Penyngton Kirkman, 1849, in Archibald, pp. 379-380. Recall chapter 2 for information about Kirkman.

[131]The *Ladies' Diary* also had a Woolwich editor from 1754 to 1760. Thomas Simpson, Master of Mathematics at the Academy from 1743 to 1761, was a self-taught mathematician and in 1750 wrote several excellent mathematical textbooks. Niccolò Guicciardini, *The Development of Newtonian Calculus in Britain 1700-1800* (Cambridge: University Press, 1989), p. 61.

[132]*Ibid.*, p. 115.

[133]Peter Wallis, *et. al.*, *Mathematical Tradition in the North of England* (Durham: NEBMA, 1991), p. 13.

[134]Guicciardini, p. 112. The depth of Gregory's relationship with Hutton may be indicated by the name of Gregory's son, Charles Hutton Gregory. Sir Leslie Stephen and Sir Sidney Lee, ed., *The Dictionary of National Biography*, (London: Oxford University Press, 1885-1901) s.v."Gregory, Olinthus Gilbert."

already in his tenth year of retirement from Woolwich, passed the editorship of the *Ladies' Diary* to Gregory. Two years later, Gregory, in turn, passed on the editorship of the *Gentleman's Diary*, which he had directed since 1804, to Thomas Leybourne, mathematical master at the Royal Military College in Marlow (later Sandhurst).

The *Gentleman's Diary* began in 1741 with contents "[s]imilar to those in the *Ladies' Diary*, but generally of greater difficulty."[135] Although Leybourne tried to increase its scientific contents and eliminate the journal's charades and enigmas in 1834, Wilkinson, in his 1848 review of mathematical periodicals, reported that two years later "he was again induced to readmit a portion of these 'ingenious puzzles.'"[136]

Leybourne established a more exclusively mathematical journal in 1795 with the *Mathematical and Philosophical Repository*.[137] Like the *Diaries*, the journal was composed of problems-for-answer whose utility, Leybourn described, "will be readily admitted when it is considered, that almost all the improvements which the mathematics have received, have originated in the exertions made to resolve particular problems."[138] In addition, the *Repository* also included original papers, translations,

[135]Thomas Turner Wilkinson, "Mathematical Periodicals," *Mechanics Magazine* 48 (1848): 56-57 on p. 57.

[136]*Ibid.* Leybourne was able to add mathematical appendices from 1835 to 1839. His editorship ended with his death in 1840; during the next year, the journal merged with the *Ladies' Diary* to form the *Lady's and Gentleman's Diary* that continued until 1871. Archibald, p. 383. The *Athenaeum* gave the following witty report of the merger: "Last year, we believe, the two mathematical almanacs, the Lady's Diary and the Gentleman's Diary, were united: the Gentleman being about 120 years old, the Lady about 140. We take an interest in these publications, in which so many English mathematicians have commenced their career. The joint publication, we think, ought to state the age of the parties in the title-page, as the individual ones used to do: is it that the Lady objects to appear as twenty years older than her husband?." [Note], *Athenaeum* (1843), p. 1107, quoted in "Gleanings Far and Near," *Mathematical Gazette* 40 (1930): 186.

[137]The *Repository* ran through two series, the first from 1795 to 1804 consisted of 14 numbers, and the second from 1804 to 1835 had 24 numbers.

[138]Thomas Leybourn, "Advertisement," *Mathematical and Philosophical Repository n.s.*, 1 (1806).

and abstracts "least likely to fall into the hands of general readers."[139] In his work on the development of calculus in Britain, Niccolò Guicciardini assessed the first three volumes in the new series of Leybourn's *Repository* as "one of the most important works in the reform of the British calculus."[140]

Throughout the eighteenth century, British mathematicians and educators had tenaciously adhered to the fluxional notation used in Isaac Newton's articulation of the calculus, despite notational innovations on the Continent. This "era of the Newtonian calculus... began with successes, suffered a period of crisis, and ended with serious attempts to reform."[141] In his 1808 review of Pierre-Simon de Laplace's *Mécanique céleste*, John Playfair described the crisis and called for reform. He claimed that the deficiencies in British understanding of continental mathematics were so great that "a man may be perfectly acquainted with every thing on mathematical learning that has been written in this country, and may yet find himself stopped at the first page of the works of Euler and D'Alembert."[142] Rather than the difficulty being the difference of notation or the style of the authors, Playfair wrote that this difficulty derived "from want of knowing the principles and the methods which they take for granted as known to every mathematical reader."[143] Concerning British mathematicians capable of reading Laplace's work, Playfair claimed, "we shall not hardly exceed a dozen."[144]

Articles in Leybourn's *Repository* addressed these concerns by utilizing and pre-

[139] *Ibid.*
[140] Guicciardini, p. 116.
[141] *Ibid.*, p. 139.
[142] Playfair, p. 281.
[143] *Ibid.*
[144] *Ibid.*

senting continental mathematical methods. Major contributors and fellow mathematical masters at the Royal Military College, William Wallace and James Ivory, employed differential notation in their contributions by 1807.[145] Additionally, Wallace translated for the journal contemporary French memoirs by Joseph-Louis Lagrange and Adrien-Marie Legendre.[146]

Besides the frequent articles by Wallace and Ivory, Gregory and his colleague Peter Barlow at Woolwich were also major contributors to the *Mathematical Repository.* The English military colleges formed the focus for this journal; in fact, contributors outside of these military colleges accounted for only about about one-fourth of the solutions to questions and a few essays.[147]

A contemporary evaluation of the *Diaries* and the *Mathematical Repository* comes from a challenge published in the *Philosophical Magazine* addressing the comments Henry Meikle had made earlier in the *Magazine* about the worth of these journals. While Meikle had deprecated British mathematical journals, the anonymous author of this rebuttal believed that

> [T]he mathematical sciences in this country owe the most solid obligations to those periodical publications. He [Meikle] would know, that while the managers of some learned societies have for many years laboured hard to stifle mathematical knowledge, those publications, by presenting a strong

[145]Guicciardini, pp. 116-117.

[146]Alex D.D. Craik, "Calculus and Analysis in Early 19th-Century Britain: The Work of William Wallace," *Historia Mathematica* 26 (1999): 239-268 on p. 245. These translations appeared as J.L. Lagrange, "Solutions of Some Problems Relative to Spherical Triangles; Together with a Complete Analysis of These Triangles," and "An Essay on Numerical Analysis, on the Transformations of Fractions," *Mathematical Repository* 1 n.s. (1806): 1-23, 24-40; Adrien Marie Le Gendre, "A Memoir on Elliptic Transcendentals," *Mathematical Repository* 2 n.s. (1809): 1-34. The calculus reforms of Wallace and Ivory also extended to the publication of articles in encyclopedias. See Craik, p. 246 and Guicciardini, pp. 119-121.

[147]Guicciardini, pp. 116-117.

> and varied stimulus to young investigators, have done as much if not more than even Cambridge and Oxford to keep it alive: – he would know that some of the able philosophers from France, Germany, Denmark, and other countries, who have recently visited England, have so highly appreciated the value of *three* of those publications, viz. The Ladies' Diary, The Gentleman's Diary, and Leybourn's Mathematical Repository, as to take back with them complete series of each, that they might introduce into their own respective countries works formed upon the models of ours; or, as Mr. M. would say, might 'torment *them* with such nonsense.'... Mr. Meikle affirms that those periodical publications are 'mostly made up of *mere puzzling questions, totally useless and unconnected with science*.'... This gentleman should... recollect that an inquiry which, at first sight, appears merely speculative, may ultimately be found of practical utility.[148]

The anonymous writer above was not alone in valuing and supporting these journals. Leybourne's *Repository* ran for forty years, while the *Diaries* enjoyed substantially longer runs. However, these journals formed the exception rather than the rule among independent mathematical serials. The average life of the 32 eighteenth-century mathematical serials listed by Archibald is seven years;[149] moreover, 21 of these lasted for only five years or less (see Table 3Ca).[150] In the case of *Miscellanea Curiosa Mathematica*, for example, although there was a large enough demand to warrant the serial's creation, expenses related to printing the mathematical material most likely contributed to is demise nine years after its foundation in 1845. Edward Cave, founder of the *Gentleman's Magazine*, launched the mathematical journal "in order to satisfy his mathematical correspondents, who were beginning to request too

[148]Mathematicus, "Defense of English Periodical Mathematical Works, in Reply to Mr. Meikle," *Philosophical Magazine* 54 (1819): 367-369 on pp. 368-369.

[149]Even this is an overestimate. Here, we consider a serial to last one year even if it only published one number in that year.

[150]For 23 of these journals, Archibald had information about the numbers issued in each journal's life. The average number of issues for these journals is about 14. Without counting the *Miscellaneous Correspondence*, which had 108 issues, the average is about nine.

much space in the *Gentleman's*."[151] However, costs associated with the meticulous editing, proofreading, and printing of mathematics caused the *Miscellanea Curiosa* to cost more than its parent journal.[152]

Most mathematical serials that survived into or were established in the nineteenth century fared only a little better than those of the century before. Of the 27 nineteenth-century journals listed by Archibald, 13 survived for five years or less (see Table 3Cb). While the average duration of these journals was about 25 years, if the five longest-lived journals are excluded,[153] this average falls to about nine years.[154]

Ten of the 16 most impermanent journals among this group lived and died between 1811 and 1831. Even as existing serials were failing, editors and proprietors of new journals enthusiastically entered the publication arena to carry the journalistic torch for mathematics. A network of overlapping support and interest formed between the editors of these periodicals. Besides contributing to their own journals, at least ten of the 17 editors of these journals were major contributors to other journals in this group.[155] For example, John Ryley, John Gawthorp, and John Whitley, subsequent editors of the *Leeds Correspondent*, all contributed to the *Enquirer* (1811-1813) and the *Quarterly Visitor* (1813-1815).[156] Not surprisingly, the *Leeds Correspondent* be-

[151] C. Lennart Carlson, *The First Magazine: A History of the Gentleman's Magazine* (Menasha, WI: The George Banta Publishing Co., 1938), p. 25.

[152] *Ibid.*

[153] These journals are: the *Ladies' Diary* (1704-1840), the *Gentleman's Diary* (1741-1840), Davis's version of the *Gentleman's Diary* (1741-1814) (this journal, however, ran for only three volumes), the mathematical column of the *Educational Times* (1847-1915), *Mathematical Questions... From the "Educational Times"* (1864-1918), and the *Mathematical Repository* (1795-1835).

[154] Likewise, for the 22 of these journals for which information was available, the average number of issues is about 27; however, excluding the five longest-lived journals gives an average of about 14.

[155] This information was compiled from Wilkinson's "Mathematical Periodicals" series.

[156] In addition, Ryley and Whitley later contributed to the *Liverpool Apollonius* (1823-1824) and

gan in 1814 partially based on the models of these two earlier journals.[157] In fact, the new journal posed some questions left unanswered in the *Enquirer* when it failed after publishing only 11 numbers.[158]

The full title of the third volume of the journal, *The Leeds Correspondent, a Literary, Mathematical, and Philosophical Miscellany: Consisting of Poetry, Essays, and Anecdotes; Translations of Latin and French Extracts; Answers to Mathematical Questions, &c. &c*, indicates that its contents were not strictly mathematical. Literary topics in English, French, and Latin, reviews, and biographies occupied the junior and senior departments of the journal.[159] Wilkinson notes that a "series of extracts, under the head of 'General Scientific Information,' was also added, which contained a large amount of valuable information. The mathematical department contained a few essays, a series of 'Questions for Youth,' and 'Mathematical Questions' for the exercise of senior students. Much good taste was exhibited by the editors, who were eminently successful in producing one of the most useful and valuable of the English periodicals."[160]

Sometimes the lines between the departments of the *Correspondent* could be blurred. For example, Master W. Pickup mixed mythology with mathematics when

the *Scientific Receptacle* (1825), and Ryley contributed to the *Student's Companion* (1822-1823).

[157]Thomas Turner Wilkinson, "Mathematical Periodicals," *Mechanics Magazine* 49 (1848): 203-204 on p. 203.

[158]Archibald, p. 393.

[159]Wilkinson, "Mathematical Periodicals," *Mechanics Magazine* 49 (1848): 203-204 on p. 203.

[160]*Ibid.* For the last three volumes (which were the only ones physically available for this study) the junior and senior mathematical departments occupied a considerable percentage of pages: in volume 3, 32 out of 288 pages (11%) were in the junior mathematical department, while 120 pages (42%) were in the senior mathematical department; for volume 4, 20 out of 328 pages (6%) junior, 69 (21%) senior; for volume 5, 14 out of 252 pages (5%) junior, 46 (18%) senior.

he posed the following problem for the junior mathematical section: "Cupid complained to his mother, that the Muses had taken away his apples: Clio, saith he, hath taken away 1/5; Euterpe 1/12; Thalia 1/8; Melpomene 1/20; Erato 1/7; Terpsichore 1/4; Polymnia 30; Urania 105; and Calliope, the most spiteful of them all, hath taken 360; so that I have only 5 apples left. How many apples had he at first?"[161]

Excluding the junior questions, 300 questions were posed and answered in the journal's lifetime. Of these, almost one-third focused on geometry.[162] Wilkinson considered this characteristic of most of the mathematical serials of this period and remarked that "it is evident that the efforts of Woodhouse, Peacock, Herschel, and Babbage to introduce a taste for analytics, however successful they might be at the universitites and public schools, were unavailing so far as regarded most of the non-academical correspondents of the mathematical periodicals."[163] In a preface to the fourth volume, James Nichols, the journal's proprietor, acknowledged that "[s]everal of our Mathematical correspondents complain, that the late numbers have contained a far greater portion of Geometrical than of Algebraical questions and solutions. That Geometry has assumed such a preponderance, is very true; but it is owing greatly to the complainants themselves, who, in their various contributions to the list of New Questions, have neglected to transmit many of those which relate to Algebra."[164]

---

[161] W. Pickup, *Leeds Correspondent* 3 (1819-1821): 254.

[162] Wilkinson typed and counted the questions as Algebra in General (26); Diophantine Analysis (24); Series (6); Chances (10); Geometry, Geometrical Analysis and Construction (87); Application of Algebra to Geometry, Mensuration, &c. (38); Trigonometry, Plane and Spherical (17); Astronomy (7); Fluxions (26); Hydrostatics (3); Loci, Quadrature, Rectification, &c. (22); Statics and Dynamics (34). Wilkinson, "Mathematical Periodicals," *Mechanics Magazine* 49 (1848): 303-306 on pp. 303-304.

[163] *Ibid.*, p. 304.

[164] James Nichols, "Preface," *Leeds Correspondent* 4 (1822).

By the third volume of the *Leeds Correspondent*, an advertisement appeared that announced that "[s]ix numbers of the Leeds Correspondent are now and will be hereafter regularly offered as a prize, to be adjudged BY LOTS to one Gentleman out of those who may give true solutions to the Prize Question in each number."[165] The following prize question illustrates the cross-referencing that occurred between mathematical serials:

> If a polygon be inscribed in a Conic Section, so that each of its sides except one may be parallel to a straight line given in position, then that side will either touch a Conic Section similar to the given one, or it will be parallel to a straight line given in position: Required the investigation or demonstration. N.B. The particular case of the triangle was the prize question in No. XVI of the Mathematical Companion for 1813.[166]

The pen name of the writer of this question, Amicus, belonged to John Whitley, who at that time edited the *Leeds Correspondent.* Besides posing questions, Whitley, using the pseudonyms Amicus or "N.Y.," answered four prize questions that had no other competitor.[167]

Outside the mathematical problems department, the *Leeds Correspondent* contained discussions about mathematics. In the "Miscellaneous" section of the journal for 1819, for example, a correspondent reported on a new trend among social gatherings of women:

> [I]t is my happiness to communicate to you the information, that a considerable change has taken place in one of the most genteel female circles in a neighboring town, by adopting philosophical and mathematical amusements in their select parties... The mathematic-mania, all lovely as it is, has infected many an amiable woman. Its tendency, we all know, is to

[165] [Advertisement], *Leeds Correspondent* 3 (1819-1821): 180.
[166] Amicus, *Leeds Correspondent* 4 (1822): 4.
[167] Wilkinson, "Mathematical Periodicals," 49 (1848): 203-204 on p. 204.

> enlarge, ennoble and refine the human intellect; and is it not now generally acknowledged, that women are endowed by Heaven with as large a portion of intelligence as men?[168]

In the next volume of the journal a bookseller, writing anonymously, recounted the effect of the earlier "Female Mathematicians" article on his family. He complained that soon after reading this article, the women in his neighborhood

> ...became tolerably expert mathematicians and newly fledged philosophers and (O unhappy me!) my wife among the rest. It is not much out of character, or injurious to any other person, for a Newton to forget his dinner in the labyrinthine sinuosities of philosophical reserarch... But nothing can be more prodigiously anomalous and unnatural, than for the wife of a tradesman to be puzzling her brains with the solution of a difficult problem when the dinner should be smoking hot on the parlour table, and her family partaking of it... [T]he study of Mathematics, as they are and ought to be studied, is incompatible with the matronly duties of a good housewife. Why ...should the ladies be suffered to encroach on our studies, or to intermeddle with masculine concerns?[169]

With a readership that the extracts above indicate must have included women as well as men, the *Leeds Correspondent* seemed to be in a period of expansion by its fourth volume. Nichols announced in 1822 "that the change from a half-yearly to a Quarterly mode of publication has afforded much satisfaction to several of the purchasers and contributors... At the close of the next Volume, it is not improbable, the suggestion of some friends may be adopted, in reference to a New Series printed in OCTAVO."[170] The next volume, however, ended prematurely with only three numbers. The *Leeds Correspondent*, which had begun its mathematical question department with the remains of the fallen *Enquirer*, surrendered its last questions to the *Scientific Receptacle.* This new journal began in 1825 and was edited by the Lincolnshire

[168]Didascalus, "Female Mathematicians," *Leeds Correspondent* 3 (1819-1821): 27-33.
[169]Bipliopola, "Female Mathematicians," *Leeds Correspondent* 4 (1822): 116-120.
[170]Nichols.

mathematics teacher, Henry Clay, who hoped to "elicit the latent spark of genius, to create the latent spark of genius, to create a generous and laudable emulation among the youthful votaries of science, to disseminate useful and entertaining knowledge, and to open a field for the recreation and exertion of the adept in mathematics."[171] Despite these lofty goals, the *Receptacle* expired after only four numbers.

Similar hopeful rhetoric accompanied the foundation of the *Liverpool Apollonius* in 1823. The new journal's editor, J.H. Swale, indicated his bias towards geometry and against the analytic methods of the Continent being adopted in Britain:

> [T]he Editor presents, to junior Geometricians in general, to those of Liverpool in particular, and to all promoters of the pursuits of Intellect; the first number of the APOLLONIUS: a periodical work, intended to furnish a page of record for the productions of Genius: to supply the Curious with useful and ennobling subjects of inquiry: to induce habits of THINKING: to encourage the prosecution of mathematical and physical Science: to familiarize THE STUDY OF GEOMETRY...NEWTON lamented the neglect of Geometry in his day: and, at the present, the fascinating and profound Analysis of La Grange, seems to occupy (exclusively) the attention of English Mathematicians.[172]

The two numbers of the *Apollonius* covered a variety of mathematical areas and contained reprints of memoirs by contemporary textbook writers Charles Bossut of Paris and Samuel Vince of Cambridge, the eighteenth-century French authority on the history of mathematics, Jean Etienne Montucla, and the eighteenth-century Scottish mathematicians Colin Maclaurin and Matthew Stewart. However, Swale's predomi-

[171] *The Scientific Receptacle*, quoted in Wilkinson, "Mathematical Periodicals" *Mechanics Magazine* 49 (1848): 367-368 on 367.

[172] J.H. Swale, "Advertisement," *Liverpool Apollonius* no. 1 (1823). Swale dedicated his first number to Thomas Leybourne, and his second number to the American mathematician and mathematical journal editor, Robert Adrain, "[a]s a public expression of esteem for his worth and talents." Adrain in turn contributed "A View of the Diophantine Analysis" to the second number. The promised continuation of this article did not appear because of the journal's early death. Robert Adrain, "A View of the Diophantine Analysis," *Liverpool Apollonius* no. 2 (1824): 86-91.

nantly geometrical focus is indicated by the original geometry articles, which occupied over one-third of work. Wilkinson noted that the "whole of the geometrical papers are by Mr. Swale himself, and are everywhere characterised by his usual elegance, originality, and fertility of invention. All of them possess a peculiar value to the student of pure geometry, and the historical interest attaching to many of the problems discussed will always render the Apollonius one of our most esteemed mathematical periodicals."[173] Swale provided historical details as well as his own opinions about mathematical schools in his geometrical contributions:

> To inscribe, in a given Circle, a Polygon of six Sides, so that the sides shall tend to, or pass through the given Points P,Q,R,S,T,V.... Geometers have considered this Problem, especially the *general* Case, as *very difficult.* It appears that CASTILON first published a laborious, *synthetic* Solution of it, in the 'Berlin Memoirs' for 1778: and LAGRANGE, in the same volume, has given another Solution, entirely *analytical.* Also, LEXELL, at the request of EULER, gave, in the 'Petersburgh Memoirs,' a Construction of Lagrange's Formula; but *failed* in attempting to *construct* the inscribed *Quadrilateral.* An Inference from this, would place the GEOMETRY of the FRENCH ANALYSTS on a puerile and retrograde Scale![174]

Besides its original articles, the *Apollonius*, like its predecessors, also included junior and senior mathematical problem sections. As Whitley had done with the *Leeds Correspondent*, Swale vigorously contributed to the problem section under his pseudonym, Apollonius.[175] The first number contained 19 junior and senior questions, and more than twice that many were added to the second number; however, the solutions to this second set would remain in manuscript form after the early failure of the journal.[176]

---

[173]Wilkinson, "Mathematical Periodicals," *Mechanics Magazine* 58 (1853): 306-307 on p. 307.
[174]J.H. Swale, *Liverpool Apollonius* no. 2 (1824): 51-52.
[175]Wilkinson, "Mathematical Periodicals," *Mechanics Magazine* 58 (1853): 327-328 on p. 327.
[176]Wilkinson noted that "[s]everal of the more simple problems in the two courses have since been

One factor cited in the ruin of this enterprise was Swale's decision to print a 55-page series of "Letters on the Newtonian System" by a Mr. Bar. Prescot.[177] Swale explained to his readers, "[t]hough the Editor does not profess a coincidence in all Mr. P's opinions and principles, yet, as an Advocate for unshackled, and even bold, Inquiry, (the inalienable Birth-right of Man) he feels no hesitation in extending the pages of the Apollonius, as a channel of communication; and recommending this interesting subject to the consideration of the curious."[178] Unfortunately, Swale admitted that the publication of Prescot's work preempted other mathematical articles. This publication also necessitated an increase in the price of the journal. Promising to return the price to normal in future numbers, Swale continued, explaining that "[t]he delay and defects of the present Number may derive some apology from continued Indisposition; which suspends all intellectual pursuit."[179]

In his letters, Prescot deemed Newton's "system, from beginning to end... [as] altogether supposititious and imaginary."[180] Prescot's system of the world: "shall in no wise be at variance with the senses, nor, consequently, with God's revealed history of the Creation: such as shall enable us to form all our computations for practice, in Astronomy and Navigation, directly from the real appearances and the true distances of the Sun and Moon, moving in circular orbits; and in which will,

discussed in the pages of the Gentleman's Diary, the Mathematical Repository, and the Educational Times, but the most interesting, and at the same time the most difficult portion, of this selection...has never yet found its way out of the extensive MS. Collections of the gifted Editor." Wilkinson, "Mathematical Periodicals," *Mechanics Magazine* 58 (1853): 328.

[177]Wilkinson, "Mathematical Periodicals," *Mechanics Magazine* 58 (1853): 307.

[178]J.H. Swale, "To Correspondents &c.," *Liverpool Apollonius* no. 2 (1824).

[179]*Ibid.*

[180]Bar. Prescot, "Letters on the Newtonian System," *Liverpool Apollonius* no. 2 (1824): 132-186 on p. 152.

consequently, be rejected, the expedients of eccentrics and epicycles, the deformity of elliptical orbits, and the monstrous doctrines of the Newtonian perturbations and derangements."[181] Calling Newton's physics "monstrous" was certainly not a popular or accepted British viewpoint. In the tenuous environment of commercial periodicals, one editorial misjudgement by Swale may have outweighed all of his previous labors with the *Apollonius.*

Even in the absence of such editorial errors of judgment, a commercial mathematical journal was constantly in danger of economic demise. After abstracting several of the most temporal mathematical journals, an exasperated Wilkinson evaluated such mathematical journals as "unproductive speculations." Although Leybourne's *Repository* (1795-1835) and the *Gentleman's Mathematical Companion* (1797-1826) had reached a "*comparatively* 'patriarchal age,'" Wilkinson explained that "probably some under-current of *self-sacrifice* enabled these vessels of science to ride so long in safety. Nor is the *lack* of support a thing unknown even in the present dearth of such publications. *Already* the '*Cambridge and Dublin Mathematical Journal*' has hoisted its signal of distress, and if such is the condition of a journal published at 'the first University in the world,' who can venture to predict the long continuance of its worthy contemporary, the *Mathematician.*"[182]

[181] *Ibid.*, pp. 176-177.

[182] Wilkinson, "Mathematical Periodicals," *Mechanics Magazine* 49 (1848): 5-7 on p. 6. Wilkinson's emphasis. The *Cambridge and Dublin Mathematical Journal* replaced the *Cambridge Mathematical Journal*(1837-1845) in 1846; Wilkinson correctly predicted its early demise in 1854. This journal was in turn replaced by the *Quarterly Journal of Pure and Applied Mathematics* the next year. At a higher mathematical level than Archibald's "Minor Mathematical Serials," this dynasty of journals is considered in chapter 4.

In his 1893 paper on mathematical journalism to the Association française pour l'avancement des sciences, J.S. MacKay listed the *Mathematician* among the most important journals "for the progress of mathematical science in England."[183] Started in 1843 by Thomas Stephens Davies, William Rutherford, and Stephen Fenwick, all mathematical masters at the Royal Military Academy, Woolwich, the *Mathematician* attempted to fill a void left by the cessation of Leybourn's *Mathematical Repository*. With their new journal, the editors hoped to establish a serial devoted solely to mathematics, as their mathematical master at Sandhurst had done before.[184] The Woolwich team recognized the difficulties experienced by previous mathematical journals, writing that "[i]n a commercial point of view, such undertakings as the present have invariably been attended with considerable loss, and we have no reason to anticipate that in the present case the result would, under ordinary circumstances, be materially different."[185] To handle these inevitable financial hardships, the editors and their friends formed "a society, for raising a small annual fund to meet that part of the expenses of the publication, which would not be covered by the returns from its sale."[186]

---

[183] J.S. Mackay, "Notice sur le journalisme mathématique en Angleterre," *Comptes rendu de l'Association française pour l'avancement des sciences* 2 (1893): 303-308 on pp. 307-308. The others listed were the *Cambridge Mathematical Journal*, the *Cambridge and Dublin Mathematical Journal*, the *Quarterly Journal of Pure and Applied Mathematics*, the *Oxford, Cambridge, and Dublin Messenger of Mathematics*, and the *Messenger of Mathematics*. The *Oxford, Cambridge, and Dublin Messenger of Mathematics* was established in 1862 as a "journal supported by junior mathematical students of the three universities." It and its successor, the *Messenger of Mathematics*, will be discussed in chapter 4.

[184] Thomas Stephens Davies, William Rutherford, and Stephen Fenwick, "Prospectus," *Mathematician* 1 (1843): 1-3 on p. 1.

[185] *Ibid.*, p. 3.

[186] *Ibid.*

The editors also took an innovative approach to the traditional problem-for-answer department:

> It is our intention to curtail, in some degree, the department of mathematical questions; for though we are fully impressed with a sense of the importance of this feature of the work, universal experience shows the difficulty of forming a sufficient number of new and good questions, where a fixed number must be made up by a given time; and the insertion of such as lead to mere petty details of calculation and deduction, suited only for the student's private exercise, tends not only to lead him into frivolous researches, but to create a false taste in science. We shall, hence, insert only such as involve some new principle, or require for their solution some new modes of investigation... [W]e hope to render this department free from the reproach so often applied to works of this class – that of 'creating a race of mere problem-solvers.'[187]

The editors received over 550 printable answers to the proposed questions.[188] These solutions were submitted by approximately 83 contributors.[189] However, 300 of these solutions came from only nine contributors. The top two producers of solutions, Thomas Weddle and George Hearn, both taught at the Royal Military College in Sandhurst and provided over one-fourth of these solutions. Hearn graduated from Cambridge as Sixth Wrangler[190] in 1839, then immediately assumed a professorship at Sandhurst, where he stayed until his untimely death in 1851. Weddle, unlike Hearn, did not receive a mathematical grooming at Cambridge, and he progressed to

[187]*Ibid.*, p. 2. After the presentation of its first set of problems, the editors "most earnestly urge upon them the deduction of as many consequences of the results themselves as well as the truths employed in their investigation, as they can obtain – being convinced that no other mode of study so much tends to increase the power and improve the taste of the young student." *Mathematician* 1 (1843): 41.

[188]Less than 550 solutions were published because if more than one contributor submitted similar solutions, only one solution was printed, and all the names of the contributors were listed.

[189]Several contributors wrote anonymously. Thus, the number of contributors should be considered an estimate.

[190]This distinction was Hearn's position in Cambridge's mathematical honors examination, the Tripos. For more on this examination, see chapter 5.

his Sandhurst Professorship after teaching at two secondary schools.[191]

At least 73 contributors either proposed questions (189) or submitted papers in the journal's departments of Algebra (21), Calculus and Differential Equations (8), Mechanics (6), Miscellaneous (23), Plane and Spherical Trigonometry (11), Plane Geometry (45), Probability (2), or Solid Geometry(19), as well as several small mathematical notes. Fenwick, Rutherford, and Davies (using his real name as well as his pseudonym, Pen-and-Ink) were among the top eight contributors of problems or papers; this group submitted almost half of the items. Hearn and Weddle also belonged to this group and represent the two most active contributors to the *Mathematician*; they provided over one-fifth of the journal's contributions. A little over 100 people provided all of the material for this periodical over its eight-year existence.

Although the *Mathematician* enjoyed support from a devoted band of contributors and was even reprinted in part in Germany,[192] the journal ceased to be printed after the first three volumes. Rutherford and Fenwick, who had edited the last two volumes without Davies, reported to their readers that they had hoped the journal could be continued "under other auspices," but "[t]hat hope has not been realized; and... [we] now issue the supplementary number... without being able to hold out the least hope of the blank, which is thus created in our mathematical literature, being filled up."[193] Rutherford and Fenwick had made great efforts to continue the

[191] *Dictionary of National Biography*, s.v. "Hearn, George Whitehead;" and Frederic Boase, *Modern English Biography* (London: Frank Cass & Co. Ltd., 1965), s.v. "Weddle, Thomas."

[192] Reprints of portions of the *Mathematician* were made by August Wiegand in Germany. William Rutherford and Stephen Fenwick, "Preface," *Mathematician* 3 (1850).

[193] *Ibid.*

enterprise, and had even corrected the proof sheets themselves to save money. "This labour," they explained, "became so continuous, that is occupied almost the whole of... [our] disposable time. This explanation will, the Editors trust, be satisfactory, both as a reason for the discontinuance of the work, and for any oversights that may be detected in any part of it."[194]

While the examples of the *Mathematician*, the *Liverpool Apollonius*, and the *Leeds Correspondent* illustrate the delicate relationship between publishing mathematics and establishing a sound business venture, journal proprietors repeatedly agreed to include mathematics among their pages. In the case of the *York Courant*, mathematics appeared in its own column surrounded by the customary news of a weekly newspaper.[195] This column began in 1828 under the direction of Thomas Tate, who subsequently became a successful textbook author, scientist, and educational authority.[196] Tate's column contained problems and their solutions, both supplied by the readers, and soon included a set of junior questions. As the contributors became more competitive, "increasingly irascible and, in one case, 'insolent'," the column introduced prize questions to channel this aggressiveness.[197]

By 1846, Tate had left his position as editor to become a "teacher trainer" at Battersea Training School,[198] and the mathematical column ended with the following

[194] *Ibid.*
[195] M.P Howson and A.G. Black, "A Source of Much Rational Entertainment," *Mathematical Gazette* 63 (1979): 90-98 on p. 90.
[196] *Ibid.*, p. 91.
[197] *Ibid.*, pp. 92, 95-96.
[198] Janet Burt, "The Development of the Mathematical Department of the Educational Times from 1847 to 1862" (unpublished PhD dissertation, Middlesex University, 1998), p. 94.

notice:

> TO OUR MATHEMATICAL CORRESPONDENTS. It having been intimated to us, from several quarters, that a newspaper is not the proper vehicle for MATHEMATICAL QUESTIONS, and that its columns ought to be occupied with intelligence more generally interesting, we have, in deference to the opinions of the great majority of our readers, resolved to exclude the Mathematical department at the close of this month, and to substitute in its place an increased variety of news (local and domestic), which will be much more interesting to the public generally.[199]

As a result of competitiveness, the column's difficulty had steadily increased and "[t]he indulgence of the 'general public' was lost."[200]

The *Educational Times* similarly welcomed mathematical problems whose difficulty eventually increased. However, unlike the *York Courant*, the *Educational Times* maintained this arrangement with mathematics for over 60 years and became a "veritable thesaurus for questions of all sorts."[201]

The *Educational Times* began in 1847 in association with the newly founded College of Preceptors, an organization that sought to maintain professional and academic standards among teachers.[202] Accordingly, the *Educational Times* focused on pedagogical themes including methods for teaching mathematics. Reviews of mathematical textbooks appeared as well as articles on mathematics education by University College, London Professor of Mathematics, Augustus De Morgan, and two members of the College of Preceptors, Richard Wilson and James Wharton.[203] Mathematical questions soon infiltrated the journal, and, by 1849, the department of "Mathematics

[199] *York Courant* (3 Sept 1846); quoted in Howson and Black, p. 96.
[200] Howson and Black, p. 97.
[201] Mackay, p. 308.
[202] Burt, p. 74.
[203] *Ibid.*, p. 106.

Questions and Solutions" was established.[204] Under the editorships of Wilson and Wharton,[205] the department developed the objective "to introduce amongst teachers sound methods of mathematical demonstration, [rather] than to lead a few to display the powers of their extraordinary mathematical genius."[206] A section for junior mathematical questions that ran from 1851 to 1854 extended the editors' intended audience to students as well as teachers. The subjects covered in the early years of the mathematical department were dominated by geometry and those topics treated in the British institutions of higher education.[207]

After Wharton's death in 1862, William Miller took over the editorship of the mathematical department of the *Educational Times* and held the position until 1897. Miller had made his first contribution to the journal as an 18-year-old student at the Dissenters' College in Taunton, and he had continued to contribute to the department while holding teaching positions at several institutions. His family's religious position had made it impossible for Miller to study at Cambridge, the premier British institution for studying mathematics.[208] However, the problems presented in the *Educational Times* had provided an outlet for his mathematical disposition.[209]

---

[204] *Ibid.*, pp. 113-114.

[205] Although the editors were never named in the *Educational Times*, through evidence from the journal itself and secondary sources, Burt has convincingly argued that Wilson and Wharton were the first directors of this department. *Ibid.*, p. 131.

[206] *Educational Times* (August 1850): 254; quoted in Burt, p. 116.

[207] *Ibid.*, pp. 303-304. Burt finds that for 1847 through 1862, 18% of the questions concerned Euclidean rectilinear geometry while 10% covered Euclidean circular geometry. Besides geometry, the main subject areas were "solving equations, conic sections, plane trigonometry, analytic geometry and dynamics." *Ibid.*, p. 315.

[208] Until 1856, Cambridge students were required to pass religious tests of the Anglican church before they could receive a degree. For more on the religious tests of Cambridge and other British universities, see chapter 5.

[209] Burt, pp. 129, 139.

As he made the transition from a problem solver to the editor of the mathematical department, Miller "expressed his long-held desire to see original problems posed and solved in the *E[ducational] T[imes]*. He also made his target audience very clear – distinguished mathematicians. His aims were certainly not purely didactic."[210] Besides changing the character of the mathematical department that had always been pressed for space, Miller wanted to publish a separate reprint of the department. To this end, he solicited the support of mathematicians as subscribers and contributors to his new venture.[211] The reprint, entitled *Mathematical Questions with Their Solutions Taken from the Educational Times*, began in 1864. This annual publication contained all of the mathematical material from the *Educational Times* and provided extra space for new solutions or papers. After one year, the journal could boast of contributions from British mathematicians, Sylvester, Cayley, Clifford, De Morgan, Todhunter, and Hirst as well as the foreign mathematicians Luigi Cremona and Pierre Marie Eugène Prouhet.[212]

The commitment by several of these mathematicians extended long after the début of the *Mathematical Questions*. Sylvester's questions appeared in each of the first 70 volumes;[213] he considered that some of those that remained unanswered "really contain the germs of theories."[214] Sylvester clearly considered the *Mathematical Questions* as a valuable venue for his questions, and he considered the editor to whom he

[210] *Ibid.*, p. 127.
[211] *Ibid.*, pp. 115, 316.
[212] *Ibid.*, pp. 322, 325.
[213] Karen Hunger Parshall, *James Joseph Sylvester: Life and Work in Letters* (Oxford: Clarendon Press, 1998), p. 127.
[214] Sylvester to William Miller, 16 Oct. 1865, in Parshall, p. 127.

had sent so many questions as

> ...an excellent mathematician, extensively and critically versed in all parts of the science, a good writer and lecturer on various subjects of natural science...and a most able and painstaking editor...His scientific attainments are of a high order; he is deeply skilled in nearly all the departments of the highest mathematics, and is a novice in none. His labour as mathematical editor of the *Educational Times*, in which his own original papers are fit company for those of our foremost analysts, is proof of that. It would be a mistake to suppose him a mere schoolmaster or a mere mathematician. He is a sound classical scholar, and an erudite man of letters.[215]

Clifford, like Sylvester, actively contributed to the *Mathematical Questions*, and he believed that the mathematical department of the *Educational Times* "has done more to suggest and encourage original research than any other European periodical."[216] Until his untimely death in 1879, Clifford "continued to furnish articles that increased in number and value through many volumes, accompanied by letters to the Editor that contained comments and developed views that were often more interesting than the articles themselves."[217] Miller developed extended relationships with world-class mathematicians such as Clifford and Sylvester although he "never broke into the higher echelons of mathematical tutors."[218] In fact, from 1876 to 1897, he pursued the avocation of mathematical journal editor while following the non-mathematical vocation of General Secretary and Registrar of the General Medical Council.[219]

Not all British mathematicians were as appreciative of Miller's *Mathematical Problems* as Sylvester and Clifford. In an 1880 article for *Nature*, Glaisher, himself an

[215]Sylvester, *Richmond and Twickenham Times* (August 17, 1889); quoted in B. F. Finkel, "Biography: W.J.C. Miller," *American Mathematical Monthly* 3 (1896): 159-163 on p. 162.
[216]Clifford, *Richmond and Twickenham Times* (August 17, 1889); quoted in *ibid.*, p. 162.
[217]Finkel, p. 161.
[218]Burt, p. 139.
[219]*Ibid.*, p. 140.

experienced mathematical journal editor,[220] evaluated the 22 exclusively mathematical journals in existence at that time. Regarding Miller's *Mathematical Questions* as well as four other international journals that contained problems for solution, Glaisher negatively commented:

> The publication of problems and solutions in a mathematical journal is always to be regretted, as it is impossible not to feel that the space might be better occupied, and that the presence of mere exercises in a periodical which should be devoted to the advance of the science is undesirable. Their insertion in several cases is doubtless due to a wish to increase the number of readers by including a class who would take but little interest in, or be unable to follow, original mathematical researches.[221]

Glaisher, however, continued in a more positive light and recognized Miller's agenda to improve the mathematical level of his readers:

> [T]he 'problem for solution' may even be defended on scientific grounds, as it is a well-known historical fact that not a few of the greatest mathematicians were first led to take a strong interest in mathematics by being tempted in their younger days to attack such questions. It may be remarked also that the mathematical problem has itself undergone great improvement since the days of the *Ladies' Diary*, when the problems usually appeared by the side of the enigmas, charades, &c. These problems were generally merely made-up exercises or puzzles - such as are to be found now only in examination papers - in which the data were wholly fictitious or even ridiculous; the modern problem, especially in pure mathematics, is often a theorem, or a particular case of a theorem, of very considerable intrinsic interest.[222]

While foreign to the *Mathematical Problems*, enigmas and charades were often the companions of mathematical problems in earlier mathematical serials. Table 3D catalogs information about the existence of these puzzles as well as other features

[220]Glaisher edited the *Messenger of Mathematics* from 1871 to his death in 1928. See chapter 4.
[221]James Glaisher, "Mathematical Journals," *Nature* 22 (1880): 73-75 on p. 74.
[222]*Ibid.*

common to these serials.[223] One such feature, a junior mathematical section, was often paired with literary sections containing French and Latin excerpts for translation in order to appeal to a student readership. A variety of other articles in the arts and sciences further extended the audiences of these periodicals, but mathematical problems for solution proved to be a staple. Even after excluding the prodigious number of problems presented in the *Educational Times* and its reprint, the journals in Table 3D printed over 6,000 mathematical problems during their lifetimes.

The editors who compiled and published these problems had a variety of educational and employment backgrounds. Table 3E presents this data for 24 of the 33 editors of the nineteenth-century mathematical serials listed by Archibald.[224] For these men, educational institutions provided a major source of employment. Over half of these editors worked at some time in their lives as schoolmasters or teachers. Six of these educators were employed at the military colleges at Woolwich or Sandhurst, one was a Cambridge Fellow, and the remainder of the teachers worked outside the university environment. Half of the editors in Table 3E authored books, typically oriented toward students, in addition to their editorial duties. This activity and the fact that some found work as booksellers or printers indicates that many of these

[223]This table considers the journals for which secondary or primary detailed information on content was available.

[224]This table uses information from John Venn, *Alumni Cantabrigienses; A Biographical List of All Known Students, Graduates and Holders of Office at the University of Cambridge* (Cambridge: University Press, 1922-54); Joseph Foster, *Alumni Oxonienses: The Members of the University of Oxford, 1715-1886: Their Parentage, Birthplace, and Year of Birth, with a Record of Their Degrees* (Oxford and London: Parker and Co., 1887-1888); *The Dictionary of National Biography*; *Modern English Biography*; and *Who Was Who, a Companion to Who's Who, Containing the Biographies of Those who Died* (London, A. & C. Black: 1897-1995).

Table 3D: Content of Mathematical Serials, 1800-1900*

Journal Title	Frequency	# of Math'l Probs.‡	Math'l Reprints	Junior Math'l Section	Original Math'l Articles	Enigmas, Rebuses, Charades	French, Latin, Literary	Other† Subjects
Ladies' Diary 1704 -1840¶	Annual	1778 (prizes)		No	Yes	Yes	No	Yes
Gentleman's Diary 1741 -1840¶	Annual	1424		No	Yes	Yes, for 1834-1836	No	Yes
Student 1797 -1800	Annual					Yes	Yes	Yes
Gentleman's Math'l Companion 1797 -1827	Annual	886	Yes		Yes	Yes	No	
Quarterly Visitor 1813 -1815	Quarterly	135			Yes		Yes	Yes
Enquirer 1811 -1813	Quarterly	155	Yes	Yes	Yes		Yes	Yes
Leeds Correspondent 1814 -1823	Semiann, then quart.	300 (prizes)	Yes	Yes	Yes	No	Yes	Yes
Scientific Receptacle 1825-1825	Quarterly	76		Yes		Yes	Yes	
Student's Companion 1822-1823	Semiann.	32		Yes		Yes	Yes	
Scientific Mirror 1829-1830	Semiann.	32		Yes		Yes		
Math'l Repository 1795-1835	Irregualar (38 nos.)	940						
Liverpool Apollonius 1823-1824	Annual	30 (prizes)	Yes	Yes	Yes	No	No	No
Northumbrian Mirror 1837-1841	Quart., triann., then semiann.	225	Yes		Yes	Yes	Yes	
Mathematician 1843-1850	Triann.	189	Yes	No	Yes	No	No	No
Educ'l Times-math'l column 1847-1915	Monthly	>19,000 (prizes: 1851-1853)	Yes	Yes, for 1851-1854	Yes	No	No	No
Math'l Questions 1864-1918	Semiann.	~19,000	Yes	No	Yes	No	No	Yes

* This information is compiled from Thomas Turner Wilkinson, "Mathematical Periodicals," *Mechanics Magazine*, 48 (1848): 56-57; 83-84;154-155; 224-226; 254-255; 342-343, 401-402; 466-468, 514; 583; 49 (1848): 5-7, 203-204, 303-306, 367-368, 437-438, 523-524; 56 (1852): 134-135; 145-147; 57 (1852): 7-9; 64-66; 245-247; 291-294; 483. Information for the *Mathematician* was found from the original source. Information for the *Educational Times* and *Mathematical Questions... From the "Educational Times"* comes from Janet Burt, "The Development of the Mathematical Department of the *Educational Times* from 1847 to 1862," (Ph.D. diss., Middlesex University, 1998). Blank entries in this table indicate that no conclusive information was available.

‡ Wilkinson does not include the number of questions from junior sections. The number of questions for the *Liverpool Apollonius* was calculated from the original source.

† Other = Almanac information (*Ladies' Diary, Gentleman's Diary*); "Polite and Useful Arts," "Natural and Experimental Philosophy," "Theoretic and Practical Chemistry" (*Student*); "Memoirs of Eminent Men," "Reviews of Books on Science and Education" (*Quarterly Visitor*); "Essays on Antiquities, Topography, Etymology, Curiosities and Coins; Account of, and Extracts from, Rare and Curious Books; Extracts and Essays on Various Subjects in the Arts and Sciences; Chemical and Philosophical Essays and Queries; Useful Recipes in the Arts and Manufactures" (*Enquirer*); extracts called "General Scientific Information" (*Leeds Correspondent*); London Mathematical Society Reports (*Math. Questions... From the "Educational Times"*).

¶ The *Ladies' Diary* and the *Gentleman's Diary* combined in 1841 to form the *Lady's and Gentleman's Diary* which possessed the same format as its parent journals and continued until 1871.

editors had close relationships with publishers. Three of these editors held memberships in a variety of British mathematical societies.[225] William Hilton, editor of the *Student*, was a member of the Oldham Mathematical Society, which was founded in 1794 and survived into the mid-nineteenth century. John Hampshire, editor of the *Gentleman's Mathematical Companion*, belonged to the Spitalfields Mathematical Society of London, which survived from 1772 until it was absorbed into the Royal Astronomical Society in 1845. Miller of the *Educational Times* was an early member of the London Mathematical Society, which in 1865 filled the void left by the Spitalfields society. As generally unprofitable enterprises, mathematical serials were not surprisingly edited by those with a commitment to teaching, writing, and supporting mathematics.

While a prosopographical analysis of the contributors to these journals is beyond the reach of this study, one distinct group of mathematicians stands out in the information available for these periodicals. Contributing heavily to a variety of journals[226] were 28 men identified by Wilkinson as part of a group who lived, worked, and studied mathematics in the north of England.

Wilkinson described early members of this group in a paper to the Manchester Literary and Philosophical Society, where he explained that

> [f]rom a very early period of our scientific history, Lancashire and the

[225]For information on these societies, see J.W.S Cassels, "The Spitalfields Mathematical Society," *Bulletin of the London Mathematical Society* 11 (1979): 241-258.

[226]The *Educational Times*, the *Enquirer*, the *Gentleman's Mathematical Companion*, the *Ladies' Diary*, the *Leeds Correpondent*, the *Mathematical Repository*, the *Mathematician*, the *Northumbrian Mirror*, *Quarterly Visitor*, the *Scientific Mirror*, the *Scientific Receptacle*, the *Student*, and the *Student's Companion*. These men were identified as heavy contributors either by Wilkinson or, in the case of the *Mathematician*, by looking at the primary source.

North have furnished their full quota of representatives to the councils of Mathematical inquiry; their hardy veterans have oftentimes led the way to brilliant and useful discoveries. Nor have these successful pioneers by any means been confined to that class of society where 'luxury and learned ease' may be supposed to have lent their aid in accelerating the progress of human knowledge.[227]

Table 3E: A Profile of Editors of Nineteenth-Century Minor Mathematical Serials * 1800-1900

Education

Village Education	Cambridge	University of Aberdeen	Dissenters' College	University of Edinburgh	Self Educated
5	2	1	1	1	1

Employment

School-master or Teacher	Book Author	Worked at Mil. College	School Owner	Publisher or or Printer	Book-seller	Clergyman	Other†
15	12	6	2	2	2	2	10

† Other= Surveyor (2), Member of the College of Preceptors (2), Bank Clerk (1), Cloth Manufacturer (1), Husbandman (1), Deputy Secretary at Nautical Almanac Office (1), Registrar and Secretary of General Medical Council (1), Cambridge Fellow (1), Cambridge Fellow (1), Lecturer at Medical School (1)

Society Membership

Fellow, Royal Society of London	Fellow, Royal Society of Edinburgh	Fellow, Royal Astro. Society	Member: Spitalfields Oldham or London Math'l Society
1	2	3	3

* This group of serials comes from those listed by Raymond Archibald, "Notes on Some Minor English Mathematical Serials," *Mathematical Gazette* 14 (1929): 379-400.

In fact, Wilkinson related that the contributions of two active contributors to several mathematical serials, James Wolfenden and John Butterworth, "were composed almost word by word whilst contemplating the requisite diagrams suspended from the framework of their looms."[228] These mathematicians from the north of England focused on geometry from a classical point of view. While strong, this group gradually

[227]Thomas Turner Wilkinson, "The Lancashire Geometers and Their Writings," *Memoirs of the Literary and Philosophical Society of Manchester* 11 (1854): 123-157 on p. 123.
[228]*Ibid.*, p. 130.

failed to pass down its traditions:

> The comparative inadequacy of the methods employed by these otherwise able men, when applied to the higher branches of Geometry, will no doubt account for the fact that of late years the taste for the strict forms of the Ancient Analysis has much declined, even in Lancashire and in the North of England... as the old Geometers, one by one, pass from the scene, their places are supplied by others who prefer the more powerful co-ordinate methods to those antiquated processes.[229]

As this band declined, so did the journals to which they contributed; with the exception of the *Educational Times*, these journals all ended by 1841. The mathematical work of these geometers indicates that contributors as well as editors of mathematical serials often operated outside of the academic sphere.

Conclusion

In his review of mathematical journals, Glaisher described an evolutionary process that he considered common to all countries:

> [F]irst, there is the Annual or other periodical, containing at the end puzzles, problems for solution, &c., the best solutions and the names of those who sent in correct solutions being given in the following number; at length these are supplemented by short articles on particular subjects — frequently suggested by the problems — by the leading contributors. The next step is the mathematical journal, consisting of two parts, the one containing original papers, and the other — quite distinct — containing a limited number of problems and solutions. Finally we have the strictly scientific journal, differing in no essential respect from the Transactions of a society.[230]

Glaisher considered Britain to have passed through all of these phases, ending with the 1865 foundation of the *Proceedings* of the London Mathematical Society.[231] However, as the discussion of commercial mathematical journals above has illustrated, the

[229] *Ibid.*, p. 156.
[230] Glaisher, p. 74.
[231] *Ibid.*, p. 75.

establishment, activity, and dissolution of these journals was not simply a progressive, evolutionary process. As British mathematicians embraced new journal formats, they did not spurn the previous ones. In fact, at the turn of the twentieth century, mathematical problems for solution could still be found in the *Mathematical Questions...from the Educational Times*, although the general level of these questions was higher than those found in most of the earlier minor mathematical serials. New formats emerged to satisfy the needs of a developing mathematical publication community. This development occurred in more than one direction, with some community members gravitating towards original research, others towards pedagogy, still others towards recreational mathematics, and some exploring more than one direction.

The nineteenth-century British publication community had access to a broad spectrum of publication outlets. With commercial journals, they could enjoy an open reception and swift publication of their articles, something not assured when dealing with societies. A mathematician could publish news and opinions quickly in *Nature*, original mathematical articles in a general scientific surrounding in the *Philosophical Magazine*, or a suggestive problem in the *Educational Times.* Moreover, budding mathematicians could enter the publication community through the junior departments of any number of minor mathematical serials. As a result of the diversity of commercial journals containing mathematics, the general British reading public was exposed to the developments, issues, and intriguing aspects of mathematics. Through these journals, the influence of mathematics extended beyond the classroom and society meeting.

The vagaries of economic trends and government taxes, however, ensured that these commercial ventures would never enjoy the stability of society publications. The *Philosophical Magazine* battled these economic forces through innovation, adaptation, and specialization. More commonly, however, independent periodicals collapsed after only a few volumes or numbers. Yet, as soon as one journal failed, motivated editors rallied to lead a new periodical. This devotion ensured the continued existence, even if under constantly changing titles, of commercial mathematical journalism in Britain.

Chapter 4: Mathematical Journals Affiliated with British Universities

As centers of mathematical study during the nineteenth century, Cambridge and Trinity College, Dublin (TCD) were quite naturally affiliated with several commercial as well as society mathematical journals. Thus, an examination of how these educational environments fostered mathematical research and publication as well as an analysis of the development of the mathematical journals of Cambridge and Dublin will provide insights into the communication, innovation, and reform reflected in British scientific journals.

This chapter explores the growth and evolution of the nineteenth-century mathematical publication venue provided by university societies and the independent efforts of students and graduates. Through an analysis of the institutional atmosphere surrounding these journals, this chapter uncovers factors that encouraged university mathematicians to begin journalistic endeavors. An examination of the economic factors that these enterprises faced explains some of the reasons for changes in the format and target audiences of these journals. Profiling the educational backgrounds and motivations of these journals' editors sheds light on a group fiercely committed to encouraging and directing the British mathematical publication community.

Cambridge Scientific Societies and Their Journals as Promoters of Mathematical Research

The mathematical education of early nineteenth-century Cambridge was generally considered as the best available in Britain.[1] This reputation resulted in large part from

[1]For example, John F.W. Herschel reported "It has ever been, and I trust it will ever continue

the Senate House Examinations, which were well established by 1735, and they soon superseded the earlier practice of disputations for determining the rank of graduating students.[2] The content of the examinations became increasingly mathematical, and competition for the highest honor bracket, the wranglers, increased the difficulty of the mathematics: "[a]lthough a very little knowledge might suffice for passing in the early nineteenth century, there was no maximum for the competition to be a wrangler."[3] As a high-ranking wrangler, a graduate gained access to promising positions in the university, church, and government.[4] Until 1850, the examinations were a required hurdle for all Cambridge students seeking a bachelor of arts degree and not just for those seeking honors and positions.[5] For example, even after a classical examination was created in 1824, its candidates were limited only to those who had sat successfully for the Senate House Examination.[6]

---

to be, the pride and boast of this University [Cambridge] to maintain, at a conspicuously high level, that sound and thoughtful and sobering discipline of the mind which mathematical studies imply." John F. W. Herschel, "Address," *Report of the BAAS* (1845), pp xxvii-xxviii; quoted in Jack Morrell and Arnold Thackray, *Gentlemen of Science: Early Years of the British Association for the Advancement of Science* (Oxford: Clarendon Press, 1981), p. 479.

[2]John Gascoigne, "Mathematics and Meritocracy: The Emergence of the Cambridge Mathematical Tripos," *Social Studies of Science* 14 (1984): 547-584 on pp. 549-550.

[3]Philip C. Enros, "Cambridge University and the Adoption of Analytics in Early Nineteenth-century England," in *Social History of Nineteenth Century Mathematics*, ed. Herbert Mehrtens, Henk Bos, and Ivo Schneider (Boston: Birkhäuser Verlag, 1981), pp. 135-164 on p. 139. Leslie Stephen made the following colorful analogy: "People sometimes ask, What is the good of horse-racing? The respectable and ostensible reply is that it improves the breed of horses. Our educational system is supposed to improve the breed of undergraduates, and in very much the same way... The examination is to the undergraduate what the race-course is to the inferior animal... The senior wrangler is the winner of the Derby." Leslie Stephen, *Sketches from Cambridge by a Don* (London: Oxford University Press, 1932), pp. 24-25.

[4]Jeremy Gray, "Mathematics in Cambridge and Beyond," in *Cambridge Minds*, ed. Richard Mason (Cambridge: University Press, 1994), pp. 86-99 on p. 87; and Gascoigne, p. 561.

[5]W.W. Rouse Ball, *A History of the Study of Mathematics at Cambridge* (Cambridge: University Press, 1889), p. 212.

[6]James W.L. Glaisher, "The Mathematical Tripos," *Proceedings of the London Mathematical Society* 18 (1886): 4-38 on pp. 15-16. By 1824, the two examinations became known as the Mathematical Tripos and the Classical Tripos; the Moral Science and Natural Science Triposes were first held in 1851. The name "Tripos" was derived from the three-legged seats on which university

While the Senate House Examination encouraged the study of mathematics at Cambridge, its contents also tightly circumscribed the mathematical subject areas that students were motivated to study. By the beginning of the nineteenth century, the content of the examination, later known as the Tripos, had become static through the following established cycle: "Students became wranglers by solving the traditional 18th-century problems that dominated the Tripos. As wranglers, they became the tutors, textbook authors and Moderators of the Tripos, passing this heritage on to the next generation of wranglers."[7] Moreover, even the outer limits of the examination topics explored by the best students, in the opinion of historian A. Rupert Hall, "bore about as little relation to the science of Laplace and Gauss as did the ancient Chinese classics."[8]

After arriving at Trinity College, Cambridge, in April 1810, Charles Babbage soon ran up against the constrictive mathematical attitude fostered by the Senate House Examination. After purchasing a copy of Silvestre Lacroix's *Calcul différentiel et intégral* for a considerable, war-inflated sum, Babbage asked his Cambridge tutor for some help with one of his "mathematical difficulties." Babbage said his tutor "listened to my question, said it would not be asked in the Senate House, and was of no sort of consequence, and advised me to get up the earlier subjects of the university studies."[9] His unhappiness with his university studies induced Babbage to transfer

representatives sat during oral examinations of degree candidates in the fifteenth century. Ball, p. 217.

[7]Harvey W. Becher, "Woodhouse, Babbage, Peacock, and Modern Algebra," *Historia Mathematica* 7 (1980): 389-400 on p. 394.

[8]A. Rupert Hall, *The Cambridge Philosophical Society: A History, 1819-1969* (Cambridge: Cambridge Philosophical Society, 1969), p. 3.

[9]Charles Babbage, *Passages from the Life of a Philosopher*, ed. Martin Campbell-Kelley (New

from the mathematically superior college of Trinity to Peterhouse College, Cambridge: "Babbage reacted to his dissatisfaction with Cambridge by ignoring as much as possible the college and university systems of studies and their rewards. He transferred to Peterhouse on April 7, 1812, probably because he would have had more freedom to pursue his own interests there than at Trinity."[10] Despite discouragement, Cambridge students began to discover continental mathematics. Sir John F. W. Herschel, who began at St. John's College, Cambridge in 1809, explained that "[t]he prestige which magnifies what is unknown, and the attraction inherent in what is forbidden, coincided in their impulse. The books were procured and read, and produced their natural effects."[11]

This self-motivated introduction by Cambridge students to continental mathematics led to the founding of the Analytical Society. The Society resulted from a May 1812 discussion between Michael Slegg of Trinity and Babbage. Slegg's comments about the distribution of Bibles by the Cambridge Auxiliary of the British and Foreign Bible Society inspired Babbage to envision a group that would distribute Lacroix's textbook.[12] Babbage's wish materialized in the same month: "[w]e constituted ourselves 'The Analytical Society'; hired a meeting-room, open daily; held meetings, read papers and discussed them. Of course we were much ridiculed by the dons; and, not being put down, it was darkly hinted that we were young infidels, and

Brunswick, NJ: Rutgers University Press, 1994), p. 19.

[10]Philip C. Enros, "The Analytical Society (1812-1813): Precursor of the Renewal of Cambridge Mathematics," *Historia Mathematica* 10 (1983): 24-47 on p. 44.

[11]John Herschel, 1832; quoted in *ibid.*, p. 31.

[12]Enros, "The Analytical Society," pp. 26-27.

that no good would come of us."[13] The 16 identified members of this new group consisted entirely of students or former graduates of Cambridge; among them, nine would become wranglers, 11 would proceed to Cambridge fellowships or professorships, and seven would be recorded in the *Dictionary of National Biography*.[14]

The student group's name described the mathematical direction that they wanted Cambridge to follow. Introduced to eighteenth-century Europe by Leonhard Euler and Joseph-Louis Lagrange,[15] analytics represented a distinct mathematical method by the nineteenth century:

> [A]nalytics implied an algebraical or formal, operational approach to mathematics. Synthetic mathematics, on the other hand, encompassed everything that was not algebraic: geometry, for example... [;]synthetics came to include, by default, all that was not strictly analytic. Fluxions, for example, although a branch of analysis, were not analytic because they involved the idea of motion, a nonalgebraic concept.[16]

Years before the Analytical Society, Robert Woodhouse had championed the analytic cause with his 1803 *Principles of Analytical Calculation.* In this work, Woodhouse followed the Lagrangian ideas of algebraic foundations for the calculus and the exclusion of limits. While his writings influenced British scholars, including Analytical Society members Babbage and George Peacock,[17] Woodhouse did not actively try to reform mathematical practices at Cambridge, where he worked as a student, Fellow, and ultimately Professor.[18] He "confined his interest in Lagrangian mathematics

[13]Babbage, *Passages*, p. 21.
[14]Enros, "The Analytical Society," p. 27, 29.
[15]Enros, "Cambridge," pp. 136-137.
[16]Enros, "The Analytical Society," p. 28.
[17]Niccolò Guicciardini, *The Development of Newtonian Calculus in Britain 1700-1800* (Cambridge: University Press, 1989), pp. 128-129; and Babbage, *Passages*, p. 19.
[18]Guicciardini, pp. 128-129.

to his private research, [and] did not provoke any scandal: he did not question the purpose of Cambridge education."[19]

In contrast, the Analytical Society did not hesitate to publicize its opinions about the past and present states of the calculus in Britain in its *Memoirs*, which appeared in November 1813:

> Discovered by Fermat, concinnated and rendered analytical by Newton and enriched by Leibnitz with a powerful and comprehensive notation, it was presently seen that the new calculus might aspire to the loftiest ends. But, as if the soil of this country were unfavorable to its cultivation, it soon drooped and almost faded into neglect, and we have now to re-import the exotic, with nearly a century of foreign improvement, and to render it once more indigenous among us.[20]

Besides stating the Society's views, the *Memoirs* also provided a place for the publication of new mathematical research. The work contained three papers written anonymously by Herschel and Babbage, who were the main presenters of papers during the Society's meetings.[21] In fact, Babbage's paper, "On Continued Products," was derived primarily from two papers he had presented earlier to the Society. Herschel's first paper discussed methods of summing trigonometrical series, while his second, "On Equations of Differences and Their Application to the Determination of Functions from Given Conditions" reflected his current mathematical interests.[22]

In Cambridge and beyond, the *Memoirs* received little notice. "At Cambridge

---

[19] *Ibid.*, p. 136. Reform measures extended beyond Cambridge with the work of the Scottish mathematicians, John Playfair, William Wallace, James Ivory, and William Spence, as well as through professors and instructors at the English military schools. Recall chapter 3, and Guicciardini, pp. 99-123. Reform in Dublin is discussed below.

[20] [Preface], *Memoirs of the Analytical Society* (1813): 15.

[21] Enros, "The Analytical Society," pp. 34-36.

[22] *Ibid.*, pp. 35-36.

the reaction was one of general bewilderment; few seemed able to understand its mathematics," and no periodical outside of Cambridge reviewed it.[23] The high cost of publishing the *Memoirs* added to the difficulties of sustaining the Analytical Society,[24] whose activity was preempted much of the time by the demands of the Senate House Examination.[25] Facing the graduation of almost all of its members and with few new recruits, the Analytical Society disintegrated in 1814.[26]

While the *Memoirs* of this society met with indifference, and although the society itself survived only two years, the establishment of this organization and its short-lived journal represented a precursor of later measures to encourage research in Cambridge. In 1819, Edward Daniel Clarke, Professor of Mineralogy at Cambridge, recognized that Cambridge provided its members with little incentive to pursue original research; he remarked that "[t]he want of a sufficient incitement towards inquiries of this nature, after University Students have commenced Graduates, has been sometimes considered as a defect in the scheme of University education. At that important period of life, when the application of philosophical studies should begin, Academical Students seem to have acted under an impression, that they have brought their studies to a

[23] *Ibid.*, p. 37.

[24] *Ibid.*, p. 40.

[25] Enros, "Cambridge," p. 141.

[26] Enros, "The Analytical Society," p. 40. After the demise of the Analytical Society, Babbage, Herschel, and Peacock focused their reform efforts on Cambridge itself. In 1816, the three mathematicians published an English translation of Lacroix's *Calcul différentiel et intégral* as a way to bring Lacroix's formulation of the differential calculus to Cambridge and also as a platform to promote their own allegiance to Joseph-Louis Lagrange's development of the calculus. Additionally, in 1820 they published two volumes of examples which made the new differential methods easily accessible to Cambridge tutors. Another opportunity appeared in Peacock's appointment as one of the two annual Moderators of the Tripos, who at that time were charged with writing and grading the examinations. Peacock held this position in 1817, 1819, and 1821 and wrote examination questions which compelled Cambridge students to abandon the old fluxionary methods. See Guicciardini, pp. 135-136, and Enros, "Cambridge," p. 143.

termination."[27] With this criticism and with hopes of correcting it, Clarke opened the first meeting of the Cambridge Philosophical Society.

Unlike the Analytical Society, the Cambridge Philosophical Society did not consider the advancement of mathematics as its sole, or even primary, object. Its two founders, Adam Sedgwick and John Stevens Henslow, operated outside of Cambridge's large mathematical sphere. Sedgwick was appointed to the Woodwardian Chair of Geology the year before the Society began. Henslow had just taken a "rather undistinguished" degree from St. John's College, Cambridge after a performance on the Senate House Examination that did not benefit from his interests in chemistry and mineralogy; in 1825, he became the King's Professor of Botany.[28] The "Preface" of the Society's first volume of *Transactions* expressed an especially encouraging attitude towards those subjects overlooked by the Senate House Examination: "the plan of the Society was not confined to those parts of Natural Philosophy, which form the more immediate objects of Academical pursuit. It was intended that the proposed Institution should embrace the studies of Chemistry, Mineralogy, Geology, Botany, Zoology, and other branches of Natural Science which have in modern times engaged so large a share of the public attention, and can be cultivated with success only by means of a continued series of experiments, and an unceasing vigilance of observations."[29]

Despite its initial leaning towards non-mathematical subjects, the Cambridge

[27]Edward Daniel Clarke, "Address Read at the First Meeting of the Cambridge Philosophical Society," *Transactions of the Cambridge Philosophical Society* 1 (1821): 1-7 on p. 4.
[28]Hall, p. 5.
[29]"Preface," *Transactions of the Cambridge Philosophical Society* 1 (1821): pp. iii-viii on p. v.

Philosophical Society was quickly infiltrated by those who wanted to promote and publish mathematical research.[30] Babbage, Herschel, and Peacock were all early fellows of the Society. Although Babbage soon became more involved in the Royal Astronomical and Statistical Societies, Herschel continued to provide communications even when away at the Cape of Good Hope, and Peacock held each of the Society's three main offices.[31] William Whewell, a Second Wrangler for 1816 and Fellow of Trinity College who would later become a major architect of the Cambridge mathematical curriculum,[32] repeatedly held Society offices and presented at least 23 papers during the society's first decade that ran the gamut from geometry to Gothic architecture.[33]

The Cambridge mathematicians who welcomed the foundation of the Cambridge Philosophical Society were soon able to seize the publishing opportunity offered by its publications. Two years after its inception, the Society began to publish its *Transactions*. The Society's leaders believed that without a central publication venue for Cambridge men, "the philosophical contributions of the members of this University [were] being frittered and squandered away in detached and distant parts."[34] Cambridge mathematicians soon regarded the society's new journal as a focal point for their research. In fact, 53.3% of the pages of the *Transactions* up to 1836 contained

[30]Only graduates of Cambridge could become fellows of the Cambridge Philosophical Society, and only MA holders could become Council members. However, honorary memberships were open to graduates of other universities. In 1872, an Associate class opened to those who were not graduates but lived in the vicinity of Cambridge. Hall, pp. 62-63.

[31]*Ibid.*, pp. 11-12.

[32]Harvey W. Becher, "William Whewell and Cambridge Mathematics," *Historical Studies in the Physical Sciences* 11 (1980): 1-48 on p. 3.

[33]Hall, p. 12.

[34]Clarke, p. 3.

mathematics; this percentage climbed to 68.6% for the period of 1837 to 1867, and still remained high at 61.5% for 1868 to 1900. Before 1838, over 40% of these pages were devoted to mathematical physics, and although this percentage fell for the two later periods of the nineteenth century, it still represented the most popular category for the *Transactions*'s mathematical articles (see Table 4A).[35] Mechanics also occupied a significant portions of the pages in the *Transactions.* The prominent place of these two applied mathematical areas in a Cambridge journal is not surprising in light of the emphasis of "mixed" mathematics at the University.[36] However, the pure mathematical areas of analytic geometry and differential and integral calculus also have page averages for the century of over 10%.

One of the most prolific contributors to the *Transactions* of the 1830s who gave interesting articles on both pure and applied subjects was George Green.[37] In 1828, researching mathematics on the side while working in his family's milling business in Nottingham, Green had privately published a treatise in which he articulated his famous theorem providing a relationship between line and surface integrals. Edward Bromhead, Fellow of the Cambridge Philosophical Society, as well as the Analytical

[35]As in table 2B, the percentages for 1868-1900 for table 4A are based on the categorizations of the *Jahrbuch über die Fortschritte der Mathematik.* For more on the *Jahrbuch* categorization and periodization this table, see chapter 7.

[36]For more on Cambridge's "mixed" mathematics, see chapter 7.

[37]Green made eight contributions from 1833 to 1839. Other prolific contributors (who, however, contributed over a much longer period) to the *Transactions* were George Airy, Cambridge Senior Wrangler, Plumian Professor of Astronomy and Experimental Philosophy and, in 1836, Astronomer Royal, who made 20 mathematical contributions from 1827 to 1864; Trinity College, Cambridge Master, William Whewell, with ten mathematical articles from 1821 to 1851; G.G. Stokes, Lucasian Professor of Mathematics at Cambridge (12 from 1842 to 1858); and Augustus De Morgan, Cambridge graduate and University College, London Professor of Mathematics (27 from 1833 to 1866).

Table 4A: The Mathematical Content of the *Transactions of the Cambridge Philosophical Society*, 1800-1900

Category	1821-1836		1837-1867		1868-1900		Total	
	#†	pg. %	#	pg. %	#	pg. %	#	pg. %
Other	1	1.2%	2	1.3%	-	-	3	0.8%
Algebra	5	11.1%	8	4.0%	5	2.9%	18	5.3%
Analytic Geometry	4	2.9%	8	8.9%	14	18.6%	26	11.1%
Comb. & Prob.	-	-	8	7.5%	2	2.4%	10	3.7%
Diff.& Int. Calc.	6	14.2%	6	5.6%	9	15.1%	21	11.2%
Function Theory	-	-	-	-	10	11.0%	10	4.2%
Geodesy & Astro	3	4.5%	2	1.5%	5	5.3%	10	3.7%
Higher & Sec. Arith.§	-	-	-	-	5	6.5%	5	2.5%
Hist. and Phil	-	-	7	10.6%	1	1.1%%	8	4.5%
Math'l. Physics	22	40.1%	29	28.8%	16	24.3%	67	29.8%
Mechanics	21	19.4%	20	22.6%	2	2.0%	43	14.0%
P.E.S. Geom. ‡	-	-	4	1.9%	4	9.6%	12	4.3%
Series	4	6.6%	6	7.5%	2	1.1%	12	4.8%

† "#" denotes the number of articles, "pg. %" denotes the percentage of mathematical pages.

‡ 'P.E.S. Geom." means "Pure, Elementary, and Synthetic Geometry." For more on these categories, see chapter 7.

§ "Higher and Secondary Arithmetic" is a *Jahrbuch* category roughly equivalent to number theory. See chapter 7.

Society before it, and one of the few subscribers to Green's publication, successfully encouraged Green to publish in the *Transactions.*[38] Bromhead also convinced him to attend Cambridge, where, in 1837 at 44 years old, he graduated as Fourth Wrangler and was elected a Fellow of the Cambridge Philosophical Society.[39]

Six months before his election, Green contributed an article "On the Motion of

[38]Although Bromhead was also a Fellow of the Royal Societies of London and Edinburgh, he considered the Cambridge Philosophical Society "the appropriate outlet for the publication of new works." After Green had two papers read to the Society within a space of only six months, Bromhead suggested that he send a third paper to the Royal Society of Edinburgh, which he viewed as "the obvious alternative, since the Royal Society of London was not to be considered at this time." Doris Mary Cannell, *George Green: Mathematician and Physicist 1793-1841* (London: Athlone Press, 1993), p. 79. Green was elected a Fellow of the society in 1837. Before his election, his papers had to be "communicated" by a Fellow. This practice was maintained until 1965. P.T. Johnstone, "100 Not Out," *Mathematical Proceedings of the Cambridge Philosophical Society* 100 (1986): 1-4 on p. 2.

[39]Hall, p. 21.

Waves in a Variable Canal of Small Width and Depth" to the Society. In what Grattan-Guinness deemed a "pioneering contribution,"[40] Green considered the motion of waves in an infinitely long canal and produced an approximate solution to the differential equation describing this motion. Although he did not explain how close his approximation came to the true solution, Green did provide the basic ideas for several subsequent investigations.[41] With this paper, and a subsequent note appearing in 1839, Green presented to the Society innovative research on hydrodynamics.[42]

For Green and many other mathematicians, the *Transactions* of the Cambridge Philosophical Society represented a primary publication venue during its first two decades. In 1844, this venue widened with the establishment of the *Proceedings* of the Cambridge Philosophical Society. This new periodical contained abstracts or full accounts of all communications made to the Society.[43] Like other British scientific societies' secondary publications, the *Proceedings* eventually eclipsed the *Transactions*, and in 1928 was made the major publication of the Society.[44] Despite its expansion in publications, the Society had experienced a lull in membership by 1850 that devel-

[40]Ivor Grattan-Guinness, "Mathematics and Mathematical Physics from Cambridge, 1815-1840: A Survey of the Achievements and of the French Influences," in *Wranglers and Physicists*, ed. Peter M. Harman (Manchester: University Press, 1985): 84-110 on p. 100. George Green, "On the Motion of Waves in a Variable Canal of Small Width and Depth," *Transactions of the Cambridge Philosophical Society* 6 (1838): 457-462.

[41]Arthur Schlissel, "The Development of Asymptotic Solutions to Linear Ordinary Differential Equations," *Archive for History of Exact Sciences* 16 (1976-1977): 307-378 on pp. 313-314.

[42]Grattan-Guinness, pp. 105. George Green "Note on the Motion of Waves in Canals," *Transactions of the Cambridge Philosophical Society* 7 (1839): 87-95.

[43]Hall, p. 36.

[44]*Ibid.*, p. 69. By the 1920s and 1930s "the *Proceedings* became such in name alone, since many papers read were never printed, and many papers printed had never been read." *Ibid.*, p. 40. For the similar developments in the periodicals of the Royal Society of London and other British scientific societies, recall chapter 2.

oped into a dramatic slide by the turn of the century.[45] Only graduates of Cambridge could be elected as members, although graduates from other universities could become honorary members. In addition to these two membership classes, in 1872, a new class of associate member was created. These members, who were required to be resident at Cambridge or the vicinity, could be elected for three-year, renewable periods.[46] Thus, Cambridge and university education formed the two foci of the Society.

With this decline in membership, the economic health of the Society also worsened, and monetary concerns delayed the publication of the *Transactions*. In these lean years, the Society's journals provided a constant drain on the Society's income;[47] however, the possibility of exchanging periodicals with other societies helped the Society to amass a library that greatly aided scientific research in Cambridge. This library had been located in the Society's house; however, financial concerns forced the sale of the premises in 1865, and the library was moved to University rooms. Possibly, the loss of the house encouraged the drop in membership, since it made the Society "much less attractive as a club."[48] After 1880, membership was no longer needed to gain access to the library because of an agreement through which the Society gave Cambridge professors and other staff members the right to use its library in exchange for larger University accommodations. While this agreement might have been a further deterrent to membership, "[i]n this way the Philosophical Library

[45] *Ibid.*, p. 71. By 1840, the Society's membership was above 500, but by the beginning of the twentieth century, the number of members had dipped to below 300. *Ibid.*

[46] *Ibid.*, p. 63.

[47] *Ibid.*, pp. 27-28, 68.

[48] *Ibid.*, p. 67.

became, in effect, a valuable element in the University library system."[49]

James W. L. Glaisher, at the time Treasurer of the Society, believed that the publications of the Society, especially the *Proceedings*, might also improve the scholarly health of the organization. Writing in 1876 to Society Fellow Stokes, Glaisher discussed the agenda of the committee appointed to consider a reform of the *Proceedings.* This proposed reform, based on the format of the Royal Society *Proceedings*, included printing the *Proceedings* with more frequency (a goal of one number per university term), and printing short papers in their entirety, "such papers to be printed by the secretaries if they know the authors, & regard the papers as being primâ facie good, without their having to be reported to referees in all cases as at present."[50] Glaisher regarded these considerations as vital: "I think the only hope of regenerating the Society is by the *Proceedings*: if we could publish them quickly i.e. in the term & *circulate them abroad at once*, we should then get good papers & become active again."[51] Apparently, Glaisher's concerns were taken seriously[52] because 1876 represents a turning point for the frequency and length of the *Proceedings.* The average time between each nineteenth-century number of the *Proceedings* after 1876 was almost a third of that for the previous numbers, and the average length of each number after 1876 doubled.

Like Glaisher, Cambridge mathematicians were active as officers of the Society

[49] *Ibid.*, p. 30.

[50] James W.L. Glaisher to G.G. Stokes, Stokes Papers, Cambridge University Library, Add 7656, 6 June 1876.

[51] *Ibid.* His emphasis

[52] The adoption of one of the above considerations by the Society is indicated by an 1880 letter from Glaisher to John Couch Adams. Glaisher asked Adams to help judge a paper and stated that "[t]he publication of papers in the Proc. rests with the secretaries (that is practically with myself) & they are not referred except in cases of doubt." James W.L. Glaisher to John Couch Adams, Adams Papers, St. John's College, Cambridge, 29 March 1880.

throughout the nineteenth century. The Cambridge reformers George Peacock and William Whewell both served as President and Secretary; Peacock also served as Treasurer.[53] From applied mathematics, G.G. Stokes, John Couch Adams, James Clerk Maxwell, G.H. Darwin, J.J. Thomson, and Joseph Larmor each served as President.[54] From the other side of the mathematical aisle were the Society officers, Arthur Cayley, Glaisher, Norman M. Ferrers, Andrew R. Forsyth, and Ernest W. Hobson.[55] Of the 82 years the Society existed during the nineteenth century, mathematicians served as President for 30 years, and a mathematician occupied one of the secretary positions continuously except for the years 1866 to 1877 and 1883 to 1887.[56]

While Augustus De Morgan was a stern critic of the Cambridge educational system, he praised the Cambridge Philosophical Society and its *Transactions*, writing that the journal gave "sufficient proof... that the ordinary system of University reading, which crams details of methods, put together in examination form, with fearful rapidity upon the young student, does not destroy the power of reflecting upon the basis of mathematical knowledge, or physical."[57] The Society provided a forum and a publication venue for this reflection, and the opportunities it provided for commu-

[53]Hall, pp. 97-104. Peacock served as President from 1841 to 1842, Secretary from 1821 to 1825, and Treasurer from 1834 to 1838. Whewell served as President from 1843 to 1844 and Secretary from 1826 to 1841.

[54]The nineteenth-century tenures of these mathematicians were: Stokes (President, 1859-1860, Secretary, 1851-1853), Adams (President, 1861-1862, Secretary, 1854-1857), Maxwell (President, 1875-1876), Darwin (President, 1890-1891), Thomson (President, 1894-1895), and Larmor (President, 1898-1899, Secretary, 1886-1895).

[55]The nineteenth-century tenures of these mathematicians were: Cayley (President, 1869-1870), Glaisher (President, 1882-1883, Treasurer 1876-1877), Ferrers (Secretary, 1858-1865), Forsyth (Secretary, 1889-1889), and Hobson (Secretary, 1890-1892).

[56]Hall, pp. 97-104. Two of the 12 nineteenth-century treasurers were mathematicians. As many as three secretaries served simultaneously.

[57]Augustus De Morgan, quoted in Tony Crilly, "The *Cambridge Mathematical Journal* and its Descendants: 1830-1870," pp. 1-34 on p. 4, to appear (page numbers refer to the preprint version).

nication were enthusiastically seized by Cambridge mathematicians.

Mathematical Journalism in Dublin

While Cambridge was a nineteenth-century mathematical center that witnessed the formation of the Analytical Society and supported the long life of an increasingly mathematical Philosophical Society, it was not the only university in Britain to place a strong emphasis on mathematical studies. Trinity College, Dublin, by the mid-nineteenth century, boasted a thriving school of mathematicians. Like Cambridge, TCD owed its focus on mathematics in large part to a university examination. For three centuries, an examination was required for the election to fellowships at the University of Dublin.[58] Although the examination included material on logic, ethics, and classics, by the close of the eighteenth century it had a mathematical focus,[59] and by 1830, mathematics and theoretical physics had gained "complete ascendancy" over the other subjects.[60] As a result of the examination, fellows, and therefore the academic personnel, overwhelmingly possessed mathematical prowess; students aiming for fellowships after graduation directed their studies towards gaining mathematical ability.[61] Mathematics also figured prominently in the examinations for the gold medals awarded to honor students upon their graduation. These medals were

[58]Trinity College, Dublin is the one college of the University of Dublin, the latter "a most elusive and shadowy entity... [which] has never had even a well-grounded formal existence... [T]he College was from its foundation vested with the powers, functions and status of a university, so that the single corporation then established must be regarded as a unitary body with collegiate and university aspects." R.B. McDowell and D.A. Webb, *Trinity College 1592-1952: An Academic History* (Cambridge: University Press: 1982), p. 4.

[59]T.D. Spearman, "Four Hundred Years of Mathematics," in *Trinity College Dublin and the Idea of a University* ed. Charles Hepworth Holland, (Dublin: Trinity College Dublin Press, 1991), pp. 280-293 on p. 281. Only in the 1920s was this system abandoned for one that considered the published work of the fellowship candidates.

[60]McDowell and Webb, p. 128.

[61]*Ibid.*

established in 1793 and by 1815 were limited to one in science and one in classics. For the science medal, as for the fellowship examination, a proficiency in mathematics and physics was key.[62]

Although it was a focal subject for honors students, mathematics for the average early nineteenth-century student was far less stringent: "[he] must be presumed to have simply picked up, along with his astronomy and his optics, the geometrical theorems and trigonometrical formulae which he required, and to have mastered them more by an effort of memory than by any full understanding of the principles involved."[63] Impressive mathematical reforms came to TCD following the election of Bartholomew Lloyd to the professorship of mathematics in 1813. Central to Lloyd's reform was the introduction to the College's curriculum of French mathematical textbooks as well as those written in English on continental methods.[64] Dionysius Lardner, a recent graduate of the College, in 1820 attested to the benefits of Lloyd's changes, writing that "[b]y the impulse which it thus received, the study of mathematics has leaped a chasm of a hundred years, and men who, according to the system pursued two years before the advancement of Dr. Lloyd to the Professorship of Mathematics, would be employed in fathoming the mysteries of Decimal Fractions, are rather more respectably employed with the *Méchanique Céleste.*"[65] In fact, while

[62]*Ibid.*, p. 90. Further restructuring in 1833 allowed students to specialize by sitting the examination covering the subject (classics, mathematics, or ethics and logic) in which they were most able. *Ibid.*, p. 174.

[63]*Ibid.*, pp. 47-48.

[64]A.J. McConnell, "The Dublin Mathematical School in the First Half of the Nineteenth Century," *Proceedings of the Royal Irish Academy* 50 (1944-1945): 75-86 on p. 76.

[65]Dionysius Lloyd, *Elements of Theory of Central Forces*, 1820, in *ibid.*, pp. 76-77.

a graduate at the turn of the nineteenth century who sought a fellowship prepared for his examination by reading "Newton's *Arithmetic*, Hamilton's *Conic Sections*, Newton's *Optics*, MacLaurin's *Fluxions*, and selections from the *Principia*," by 1822, a student seeking a Science Gold Medal needed to study the much more rigorous "Woodhouse's *Trigonometry*, Lardner's *Algebraic Geometry*, Lacroix's *Calcul Différentiel et Intégral*, Lacroix's *Théorie des Lignes Courbes*, Lloyds's *Mechanical Philosophy*, Poisson's *Mécanique*, and selections from Newton's *Principia* and Laplace's *Mécanique Céleste*."[66]

Besides his curricular changes, Lloyd also sought to alter the College's mathematical leaders by encouraging the election of young, creative men to the mathematical chairs.[67] William Rowan Hamilton was elected to the Andrews Chair of Astronomy (also known as the Astronomer Royal of Ireland) as a 21-year-old undergraduate in 1827, and eight years later, James MacCullagh assumed the chair of mathematics at the age of 27.[68] While Hamilton did much distinguished mathematical research in his position, his isolated residence at the observatory at Dunsink discouraged any mentoring of College students.[69] It was MacCullagh who inspired promising College students in their pursuit of mathematics. From his appointment in 1835 to his death

[66]McConnell, pp. 76-77.

[67]*Ibid.*, p. 77.

[68]Lloyd had left this chair in 1822 for the chair of natural philosophy; in 1831, he became provost. At the time that MacCullagh assumed the chair, Francis Sadleir, a Senior Fellow, was "bought out" of this position, which he regarded as a steady addition to his income. Lloyd, as provost, worked for this chair to be funded well enough to allow someone to devote all of his time to it. T.D. Spearman "James MacCullagh," in *Science in Ireland 1800-1930: Tradition and Reform*, ed. John R. Nudds *et. al.* (Dublin: Trinity College Dublin, 1988), pp. 41-60 on p. 41.

[69]*Ibid.*, p. 79.

12 years later, 20 honors students in mathematics became fellows.[70] Of these, several published original research, and five published some of this research abroad.[71] This group of fellows supported with their contributions the *Transactions* of the Dublin University Philosophical Society.[72] This society began in 1842 and published six volumes of *Transactions* over 12 years.[73]

Almost 20 years after the end of the Dublin University Philosophical Society, a group of professors and fellows began *Hermathena: A Series of Papers on Literature, Science, and Philosophy by Members of Trinity College, Dublin.* In their preface to the first volume, the editors announced that they would "accept any communication which shall seem to them interesting and useful."[74] The variety of topics covered in the first volumes verified the editors' intention: classics, philosophy, Irish history, mathematics, and physics all received coverage. *Hermathena*'s early editorial board consisted of John Kells Ingram, a College Fellow and Professor of Greek (who would serve as Vice-Provost in 1898), John Pentland Mahaffy, Professor of Ancient History (who would become provost in 1914), Robert Yelverton Tyrrell, Professor of Latin, and Benjamin Wilkinson. At the launch of *Hermathena*, Wilkinson had been a Fellow at the College for 20 years. The year before, he had published a treatise on differential calculus and would publish an accompanying work on integral calculus in 1874. These

[70] Spearman, "MacCullagh," p. 42.

[71] These five were Charles Graves, John Jellett, Michael and William Roberts, and George Salmon. For information on these internationally active contributors, see chapter 6.

[72] McConnell, p. 87.

[73] Availability issues, due to the rarity of copies of this journal, have rendered this journal unavailable for review.

[74] "Preface," *Hermathena* 1 (1873): iii-iv on p. iii.

popular works went through multiple editions and were noted for their "clearness and elegance."[75] Among his fellow, classically focused editors, he must have provided a mathematical lobby for *Hermathena.* Wilkinson, however, was not the only editor of *Hermathena* with mathematical ability. Ingram had published papers on "medieval manuscripts, etymology, Shakespearean criticism and economics,"[76] but had also earlier published with John William Stubbs an innovative article on geometry in the *Transactions* of the Dublin University Philosophical Society.[77] A multidisciplinary spirit was also evidenced among some of *Hermathena*'s contributors. Charles Graves, Professor of Mathematics at the College and later the Bishop of Limerick, contributed a mathematical article "On the Focal Circles of Plane and Spherical Conics" as well as a study in Irish history "On Ogham Inscriptions."[78]

No less than five mathematical articles appeared in each of the first six volumes (1873-1888) of *Hermathena* and accounted for over 18% of these volumes' pages. However, many of these articles presented material suitable and useful for the mathematical studies of the College's students rather than innovative research-level work. In his first contribution, "On Integration by Rationalization," for example, Wilkinson presented a generalization of methods that "may be worthy of the notice of the stu-

[75]"Benjamin Wilkinson, 1827-1916," *Proceedings of the Royal Society of London*, ser. A, 93 (1916-1917): xxxviii-xli on p. xxxix. In 1879, Wilkinson was elected a Fellow of the Royal Society of London and as the Donegal Lecturer of Mathematics at TCD. From student to lecturer, his relationship with the college lasted 73 years. *Ibid.*, pp. xxxviii-xxxix.

[76]McDowell and Webb, p. 293.

[77]McConnell, p. 87.

[78]Charles Graves, "On the Focal Circles of Plane and Spherical Conics," *Hermathena* 6 (1888): 384-396; "On Ogham Inscriptions," *Hermathena* 6 (1888): 241-268. Graves also contributed "The Ogham Alphabet," *Hermathena* 2 (1876): 443-473; and "On Two Fragments of a Greek Papyrus," *Hermathena* 5 (1885): 237-257.

dent" of transforming the algebraic and rational expressions into integrable forms.[79] For example, using substitutions, he showed his readers how to transform the differential $\frac{dx}{\sqrt{A(x-\alpha)(x-\beta)(x-\gamma)(x-\delta)}}$ into the more manageable $\frac{d\theta}{\sqrt{a-k^2\sin^2\theta}}$.[80] William S. M'Cay, a College Fellow, used theorems in George Salmon's textbook, *Higher Plane Curves*, to find the so-called "anharmonic function" of a cubic, arriving at "the same equation that Dr. Salmon derives from other considerations."[81] John Christian Malet, himself a TCD student, acknowledged his debt to the "instructive Lectures" of his Professor, Michael Roberts, "for my knowledge of some of the Theorems quoted in the following paper." In his article, "On a Class of Problems Connected With Linear Differential Equations," Malet considered linear differential equations whose solutions are functions of the solutions of other such equations.[82] Of *Hermathena*'s 18 mathematical contributors, all but one had been, like Malet, educated at TCD and 12 were fellows at the institution.

Hermathena devoted considerable room to the history of mathematics with George Allman's six installments on "Greek Geometry from Thales to Euclid."[83] Allman, a College graduate and Professor of Mathematics at Queen's College, Galway, collected and printed these articles in book form in 1889.[84] Similarly, on two occasions Robert

[79] Benjamin Wilkinson, "On Integration by Rationalization," *Hermathena* 1 (1873-1874): 254-260 on p. 254.

[80] *Ibid.*, pp. 257-259.

[81] William S. M'Cay, "A Simple Method of Determining the Anharmonic Function of a Cubic," *Hermathena* 1 (1873): 261-263 on p. 263. For more on Salmon's textbooks, which were widely used by British students and mathematical researchers alike, see chapter 7.

[82] John Christian Malet, "On a Class of Problems Connected With Linear Differential Equations," *Hermathena* 2 (1876): 519-521.

[83] George Johnston Allman, "Greek Geometry from Thales to Euclid," *Hermathena* 3 (1879): 160-207; 4 (1883): 180-228; 5 (1885): 186-236, 403-432; and 6 (1888): 105-130, 269-278.

[84] George Johnston Allman, *Greek Geometry from Thales to Euclid* (Dublin: Hodges, Figgis, 1889).

Graves published manuscripts from the collection of William Rowan Hamilton in *Hermathena*.[85] Graves, who would publish Hamilton's biography in 1882, hoped to encourage "competent persons" to examine the manuscripts of Hamilton found at the College library in order to rescue unpublished work "from oblivion."[86]

While mathematics figured significantly in *Hermathena* during its first 15 years, only one other mathematical article appeared in the remainder of the next five nineteenth-century volumes. While the *Proceedings* of the Cambridge Philosophical Society became increasingly mathematical and physical, *Hermathena* became more classical, a focus it maintained in the twentieth century.[87] A poem written in 1973 to commemorate the centenary of *Hermathena* illustrated how completely the journal had left its mathematical past behind:

> ... here you'll find
> Little count or number: within these pages
> The record of man's still undigited mind
> Pleases one moment and the next enrages.
> So, at a century's end, it still is true
> That my five fingers never will serve you![88]

Although neither *Hermathena* nor the *Transactions* of the Dublin University Philosophical Society proved to be lasting publication venues for mathematics, Dublin mathematicians were explicitly invited to contribute to yet another mathematical

[85]Robert Percival Graves, "Sir W. Rowan Hamilton on the Elementary Conceptions of Mathematics," *Hermathena* 3 (1879): 469-489; and "Sir William Rowan Hamilton on the Problem of Hipparchus," *Hermathena* 4 (1883): 489-506.

[86]Graves, "Hipparchus," p. 481.

[87]Charles Benson, "Trinity College: a Bibliographical Essay," in *Trinity College Dublin and the Idea of a University* ed. Charles Hepworth Holland, (Dublin: Trinity College Dublin Press, 1991), pp. 357-372 on pp. 368-369.

[88]Monk Gibbon, "A Century of *Hermathena*," *Hermathena* 115 (1973): 116.

journal that underwent three separate incarnations during the nineteenth century. The *Cambridge and Dublin Mathematical Journal* embraced the two active mathematical centers of Cambridge and Dublin, and formed a communication network for mathematicians throughout Britain and abroad.

The *Cambridge Mathematical Journal*, the *Cambridge and Dublin Mathematical Journal*, and the *Quarterly Journal of Pure and Applied Mathematics*: A Nineteenth-Century Dynasty of Commercial Mathematical Journals

While the *Transactions* of the Cambridge Philosophical Society provided an outlet for mathematics, it failed to satiate the appetite for mathematical publication venues in Cambridge. Thus, in 1837, Duncan F. Gregory became the first editor of the *Cambridge Mathematical Journal*.[89] After studying at the University of Edinburgh where he was a "favourite pupil" of William Wallace, Gregory continued his studies at Trinity College, Cambridge. At the time the journal was launched, Gregory had just graduated from Cambridge; he would become a Fellow at Trinity three years later. First and foremost in Gregory's view, his new journal would provide "a means of publication for original papers;"[90] clearly, he felt the need to encourage Cambridge students to publish research. Secondly, it would provide the resources needed for this research "by publishing abstracts of important and interesting papers that have

[89]While Gregory "had been active in establishing it," the *Cambridge Mathematical Journal* was not entirely of his own doing. Archibald Smith, at the time a Cambridge Fellow, has been called "[o]ne of the founders" of the *Journal*. Robert Leslie Ellis, "Memoir of the Late D.F. Gregory, M.A., Fellow of Trinity College, Cambridge," *Cambridge Mathematical Journal* 4 (1843-45): 145-152 on p. 149; and John Venn, *Alumni Cantabrigienses; A Biographical List of All Known Students, Graduates and Holders of Office at the University of Cambridge* (Cambridge: University Press, 1922-54), s.v.,"Smith, Archibald." Crilly also lists Samuel S. Greatheed, the Fourth Wrangler for 1835, as a founder of the journal. Crilly , p. 5.

[90]Duncan Gregory, "Preface," *Cambridge Mathematical Journal* 1 (1837): 1-2 on p. 1.

appeared in the Memoirs of foreign Academies, and in works not easily accessible to the generality of students. We hope, in this way to keep our readers, as it were, on a level with the progressive state of Mathematical science, and so lead them to feel a greater interest in the study of it."[91]

Gregory felt confident that Cambridge contained many "who are both able and willing to communicate much valuable matter to a Mathematical periodical."[92] In fact, 21 of the 26 identified contributors to the journal had a Cambridge affiliation; this group provided at least two-thirds of the contributions.[93] The popular topics of the *Journal*'s articles, therefore, largely represent the interests of productive mathematicians writing in the 1830s and 1840s who had spent at least some of their academic careers at Cambridge. The three most popular topics for articles were analytic geometry, with 23.7% of the articles and 22.3% of the mathematical pages, Differential and Integral Calculus (18.3%; 22.5%), and algebra (10.4%; 12.2%). However, close fourth- and fifth-place finishers were the applied topics of Mechanics (10.4%; 9.5%) and Mathematical Physics (10.0%; 10.6%).[94] The prevalence of these areas reflect the Cambridge emphasis on "mixed" mathematics and the introduction of analytical reforms into the University earlier in the century.[95] The University focus of the *Cam-*

[91] *Ibid.*

[92] *Ibid.*

[93] Even after William Thomson published an index of the *Journal* which identified many pseudonyms, 63 of the 278 articles remained anonymous.

[94] These rest of the articles, classified under the *Jahrbuch* scheme used in chapter 7, fall into the following headings: Geodesy and Astronomy (5.7%; 4.4%), Series (5.0%, 4.3%), Higher and Secondary Arithmetic (4.3%; 3.6%), Function Theory (3.9%; 5.6%); Pure, Elementary, and Synthetic Geometry (2.5%; 1.0%), Combinations and Probability (1.8%; 1.9%), History and Philosophy (0.4%; 0.6%), and Other (3.6%; 1.3%).

[95] For more on "mixed" mathematics and the analytical reforms, see chapter 7.

bridge Mathematical Journal can also be seen from the frequent discussion of Senate House Examination problems in the first three volumes.[96]

While primarily a venue for Cambridge mathematicians, the *Cambridge Mathematical Journal* also represented a means for an outsider to get his work noticed by other mathematicians. George Boole, though mathematically gifted, had not attended university, and had taught from the age of 16 at various institutions in or near Lincoln. After contacting Gregory in 1839, Boole began publishing in the *Journal* and thereby introduced himself to Cambridge mathematicians.[97] Along with Gregory, Boole published several papers on the calculus of operations, a subject that would subsequently catch the imagination of a generation of British mathematicians.[98] Boole also published in the *Journal* his "Exposition of a General Theory of Linear Transformations," which can be taken as the starting point for what would be known as the British approach to invariant theory.[99]

While Boole actively contributed to the *Journal*, publishing 11 articles there from 1839 to 1845, he chose the *Philosophical Transactions of the Royal Society of London* for an extensive memoir concerning operators. He had received counsel from

[96] "Solutions of Problems in the Senate-House Papers," *Cambridge Mathematical Journal* 1 (1837-1839): 32-34, 95, 144, 282; "Solutions of Senate-House Problems," *Cambridge Mathematical Journal* 2 (1839-1841): 94-96, 142-144. Senate House Examination problems were also found among the "Solutions of Problems." *Cambridge Mathematical Journal* 3 (1841-1843): 95, 152, 292.

[97] G.C. Smith, *The Boole— De Morgan Correspondence, 1842-1864* (Oxford: Clarendon Press, 1982), p. 7.

[98] For more on the calculus of operations and its role in the development of algebra in Britain, see chapter 7. For more on these contributions of Boole and Gregory, see Elaine Koppelman, "The Calculus of Operations and the Rise of Abstract Algebra," *Archive for History of Exact Sciences* 8 (1871): 155-242 on pp. 189-200.

[99] George Boole, "Exposition of a General Theory of Linear Transformations" *Cambridge Mathematical Journal* 3 (1841-1843): 1-20. For this article and more on the development of the British approach to invariant theory, see chapter 7.

Augustus De Morgan about the most appropriate home for his work. De Morgan's response gives an interesting perspective on the publication sphere for research-level mathematics during the early 1840s:

> With regard to the manner of printing: I see no channel in this country except the Phil. Trans. the Cambridge Phil. Trans. or the Cambr. Journal. It is probably too long for the third & I am afraid Gregory is in no state to attend to or decide upon it. Whether the R[oyal] S[ociety] would print it or not is a question. I think they ought to do so, but in sending it to them there is the nuisance of keeping a copy... as they are very dog-in-the-mangerish about what they call their archives and will not return a paper even when they do not print it. The Cambr. Soc. labour under want of funds and would look suspiciously I suspect, upon anything long. I think if you do not mind copying it out you should try the R.S. in the first instance. The Phil[osophical] Mag[azine] I have no doubt would print a summary but it would be decidedly too long for that periodical.[100]

Boole took De Morgan's advice and submitted his paper to the Royal Society. Not only did the Society print the memoir, but they also awarded Boole a Royal Medal for it in 1844.[101]

De Morgan mentioned Gregory's inability to evaluate Boole's work because the editor was in the midst of a recurring illness. Gregory was first attacked by this sickness late in 1842, and by the following spring he had left Cambridge; he would not return and died at age 30 in 1844.[102] In Gregory's absence, the direction of the *Cambridge Mathematical Journal* was assumed by Robert Leslie Ellis.[103] In 1840,

[100]Augustus De Morgan to George Boole, 24 November 1843, quoted in Smith, p. 13. For an example of the Royal Society rejecting one of De Morgan's papers and their general printing policies, recall chapter 2.

[101]Smith, p. 2. The Royal Medal was awarded for George Boole, "On a General Method in Analysis," *Philosophical Transactions of the Royal Society of London* 134 (1844): 225-82.

[102]Ellis, p. 151.

[103]William Walton, the Eighth Wrangler for 1836, initially helped Ellis with this task, and the two men jointly edited the number for February 1844. Crilly, p. 9.

Ellis had graduated as Senior Wrangler and had been elected to a fellowship at Trinity College, Cambridge. After editing the *Journal*'s fourth volume, Ellis sought someone with whom he could entrust his editorial duties. He wrote to William Thomson, "I do wish you would permit me to resign the editorship in your favour. You will in all probability be longer in Cambridge than I shall, & I should be so much better pleased to see it in your hands than in mine."[104] Thomson, who would later become Lord Kelvin, agreed to Ellis's proposal and began a new series of the *Journal.*

Thomson had just returned from a semester-long sojourn in Paris after graduating as Second Wrangler. During this trip, he had begun a productive friendship with Joseph Liouville, and had introduced French mathematicians to the work of George Green.[105] With international experiences fresh in his memory, Thomson tried to widen the contributorship of his newly acquired journal. During the summer of 1845, he discussed a change of title for the *Journal* and the effects that such a change would have in the attitudes of his contributors. Ellis wrote Thomson that he had brought up these considerations with Charles Graves, the newly appointed Professor of Mathematics at TCD. Ellis reported that Graves believed the addition of the word

[104]Robert L. Ellis to William Thomson, Kelvin Papers, Cambridge University Library, Add 7342, 13 June 1845. Ellis, like Gregory, lived an unnaturally short life. By 1847 concerns about his health compelled him to go abroad, but he soon returned to England after contracting rheumatic fever. He spent several years as an invalid and died in 1859." Sir Leslie Stephen and Sir Sidney Lee, ed., *The Dictionary of National Biography,* (London: Oxford University Press, 1885-1901), s.v. "Ellis, Robert Leslie."

[105]Silvanus P. Thompson, *The Life of William Thomson, Baron Kelvin of Largs*, vol. 1 (London: Macmillan and Co., 1910), pp. 113-120. For more on Thomson's relationship with Liouville and the international contributions to the French mathematician's journal, see Jesper Lützen, "International Participation in Liouville's *Journal de mathématiques pures et appliquées*," in *Mathematics Unbound*, ed. Karen Hunger Parshall and Adrian C. Rice (Providence: American Mathematical Society and London: London Mathematical Society, 2002), pp. 89-104.

"Dublin" into the title would be impressive to those at the College: "[h]e says many of the younger men tell him they would be happy to contribute if they could look on the journal as in any degree an organ of their university."[106] In another letter, Boole, who had no university affiliation until being appointed to the professorship of mathematics at Queen's College, Cork in 1849, pointed out that such an addition to the title could "confine the Journal to a certain class of contributors."[107] In August of 1845, Graves directly counseled Thomson about the best title: "My own leaning, and I think I may say Sir Wm. Hamilton's is in favor of the name 'Cambridge and Dublin.' It appears to me most likely to conciliate the support and to stimulate the energies of men connected with this university. And I would venture to urge that the exclusiveness of the title can do you little harm."[108] No matter what Thomson's decision, Graves had "a hope amounting almost to full assurance that the friendly spirits evinced by you and Mr. Ellis and other Cambridge friends will elicit the cordial cooperation of Irish Mathematicians."[109] By November, Thomson reported his decision to Sylvester to add "Dublin" to his new series' title in view of the Dublin mathematicians "who are willing to assist in the undertaking, and to form an alliance with Cambridge."[110]

Thomson's decision was soon rewarded by a devoted group of Dublin contributors

[106]Robert L. Ellis to William Thomson, Kelvin Papers, Cambridge University Library, Add 7342, 17 July 1845.
[107]George Boole to William Thomson, Kelvin Papers, Cambridge University Library, Add 7342, 18 July 1845.
[108]Charles Graves to William Thomson, Kelvin Papers, Cambridge University Library, Add 7342, 1 August 1845.
[109]*Ibid.*
[110]William Thomson to J.J. Sylvester, Kelvin Papers, Cambridge University Library, Add 7342, 19 Nov. 1845. Thomson's move to link Cambridge and Dublin echoes Taylor's efforts to rename his journal the *London, Edinburgh, and Dublin Philosophical Magazine and Journal* (recall chapter 3).

to the *Journal.* While only two TCD mathematicians contributed to the *Cambridge Mathematical Journal,* 18 members of this group contributed almost one quarter of the contributions to the new series. This Dublin group was only second to the 25 Cambridge mathematicians who contributed half of the articles.[111]

Many of the members of Thomson's considerable Dublin contingency studied under MacCullagh and exhibited the inspiration he had given them for geometry.[112] With their help, geometrical articles accounted for around one-third of the articles and pages of the *Journal.*[113] Pure mathematics, in general, dominated the volumes, accounting for over 70% of the pages and articles. However, as the case study in chapter 7 shows, Thomson battled the tide of pure mathematics and encouraged the publication of articles on mathematical physics in the journal.[114]

Besides wishing for greater coverage of applied topics, Thomson wanted his journal to have a more professional character than its predecessor. To this end, he abolished the practice of printing articles anonymously or with pseudonyms that had been common in the *Cambridge Mathematical Journal.*[115] This practice of using pseudonyms

[111]The other contributions came from nine foreigners (who contributed 5% of the articles), five Oxford mathematicians (6% of the articles), one from Edinburgh (2% of the articles), two from military colleges (6% of the articles), one not affiliated with a university (George Boole, with 4% of the articles), and three of unknown affiliation (with 3% of the articles).

[112]McConnell, p. 81.

[113]Several of these geometrical articles are considered in the case study on analytic geometry in chapter 7.

[114]These articles of the *Cambridge and Dublin Mathematical Journal,* classified under the *Jahrbuch* scheme used in chapter 7, fall into the following headings: Analytic Geometry (28.7% of the articles; 29.7% of the pages), Mechanics (15.2%; 16.5%), Differential and Integral Calculus (14.0%; 14.0%), Algebra (13.5%; 15.5%), Mathematical Physics (8.9%, 7.9%), Pure, Elementary, and Synthetic Geometry (6.0%; 6.3%), Function Theory (4.0%; 4.0%), Higher and Secondary Arithmetic (2.6%; 0.8%), Combinations and Probability (2.6%; 2.2%), Series (1.4%, 0.4%), Geodesy and Astronomy (0.9%; 0.3%), History and Philosophy (0.9%; 0.7%), and Other (1.4%; 1.8%).

[115]Leybourn displayed his dislike of pseudonyms when he published an index of the names of contributors to the *Ladies' Diary* (recall chapter 3). Teri Perl, "The Ladies' Diary or Woman's

had been common during the eighteenth century, and was carried on into the early nineteenth century. Besides the *Cambridge Mathematical Journal*, the *Philosophical Magazine* and the *Oxford, Dublin, and Cambridge Messenger of Mathematics* also published mathematical articles anonymously. In his investigation of the *Cambridge Mathematical Journal*, Tony Crilly has pointed out that an alias "enabled an author to try out an idea without risking personal criticism from a critical readership and undergraduates published anonymously presumably under the principle that they could be heard but not seen. It was the material presented which was important and it was a matter of social form that the author should not draw attention to himself for self-advertisement."[116] Archibald Smith, in an 1845 response to Thomson's wish to identify the earlier pseudonyms, indicated the relief anonymity could afford when he wrote that "I have great objections to have my name prefixed to any articles except perhaps those on the Wave theory tho' others were the mere sweepings of any undergraduate M.S.S. to which I was ashamed even to put my initials."[117]

Beyond raising the character of his journal by eliminating aliases, Thomson also wanted the articles published in the *Journal* to reflect a high quality of research. However, aware of the perilous economic conditions faced by every independent mathematical journal, he conceded to other types of contributions that might increase subscribers.[118] In a letter to Sylvester, Thomson described the compromise he had

Almanack, 1704-1841," *Historia Mathematica* 6 (1979): 36-53 on p. 45.

[116]Crilly, p. 8.

[117]Archibald Smith, quoted in Crilly p. 9.

[118]For examples of independent journals which struggled in this publication environment, recall chapter 3.

reached:

> You will I am sure agree with me in thinking that the principal object of any scientific journal should be the publication of original investigations and discoveries, and I hope that, both commercially and mathematically, the Cambridge and Dublin Journal may be sufficiently prosperous to allow such a course to be followed. At the same time, it will in many respects, but especially that of interesting and being useful to a larger body of readers be desirable occasionally when there may be opportunity to publish papers of a more elementary kind, in which either simpler methods of proving known theorems, or more elegant forms of known results, which are met with in ordinary mathematical reading, may be given.[119]

Although Thomson was obliged to operate under this compromise, Augustus De Morgan encouraged him to get "enough of the stern stuff which an editor ought to have, to say no & send... [questionable papers] back."[120] In fact, Thomson did not fail to reject what he viewed as substandard papers for publication. Thomas Weddle, a teacher at the Royal Military College at Sandhurst and an active contributor to such minor mathematical serials as the *Ladies' Diary*, the *Northumbrian Mirror*, and the *Mathematician*, had experienced such a rejection from Thomson. As is clear from Weddle's reply, however, Thomson was very gentle in his rejection, no doubt not wanting to alienate a potentially valuable reader, contributor, and member of a larger group of readers and contributors at Sandhurst. Weddle explained that "[i]f the return of the paper was somewhat disappointing yet the cause of it and the considerate way in which the non-acceptance was couched, was rather an encouragement rather than otherwise."[121] Along with this reply, Weddle, in fact, was writing to again try to

[119] William Thomson to J.J. Sylvester, Kelvin Papers, Cambridge University Library, Add 7342, 19 Nov. 1845.

[120] Augustus De Morgan to William Thomson, Kelvin Papers, Cambridge University Library, Add 7342, 16 February 1846.

[121] Thomas Weddle to William Thomson, Kelvin Papers, Cambridge University Library, Add 7342,

contribute to the *Journal*: "[a]s I am not altogether aware what degree of originality or what subjects are 'in accordance with the object of the Journal,' I am not quite sure that the present paper will be more successful than its predecessor. I know that in the case of certain periodicals to which I am a contributor this paper would be considered admissible, but I am not so well acquainted with the spirit of the Math Journal, as to be able to judge whether its insertion may be compatible with the objects which the existence of the Journal is intended to subserve."[122] In this submission, he considered theorems about ellipsoids, explaining that "nearly every [one of which]...was discovered by me [with three exceptions]...and, of these, I discovered the demonstrations. Subsequent enquiries have however shown that some of the others also are already known."[123] Despite its lack of originality, Weddle's submission, "Investigation of Certain Properties of the Ellipsoid," satisfied Thomson's editorial criteria of presenting "simpler methods of proving known theorems" and appeared in the second volume of the *Journal.*[124]

In the third volume of the *Journal*, Weddle presented another original proof of an old theorem in his "Demonstration of Pascal's Hexagramme." In 1639, Blaise Pascal had made the fundamental discovery that the intersection points of the three pairs of opposite sides of a hexagon inscribed in a conic are collinear.[125] Weddle's was

21 July 1846.

[122] *Ibid.* For more on minor mathematical serials and Weddle's contributions to the *Mathematician*, recall chapter 3.

[123] *Ibid.*

[124] Thomas Weddle, "Investigation of Certain Properties of the Ellipsoid," *Cambridge and Dublin Mathematical Journal* 2 (1847): 13-18.

[125] Charles Coulston Gillispie, ed., *Dictionary of Scientific Biography*, 16 vols. 2 supps. (New York: Charles Scribner's Sons, 1970-1980), s.v. "Pascal, Blaise."

certainly not a new result (indeed, his article was relegated to the "Mathematical Notes" section of the *Journal*), but he claimed that his demonstration "differ[ed] materially" from earlier proofs.[126] Illustrating his knowledge of the mathematical contents of British journals, Weddle listed an extensive bibliography of the problem in this article, and extended the bibliography in a later note to the *Journal*.[127]

While Weddle after a false start eventually became a regular contributor to the *Cambridge and Dublin Mathematical Journal*, Steven Fenwick failed to make it past one of Thomson's volunteer referees. Arthur Cayley wrote to the editor that "I do not think you ought to print Fenwick's paper; almost all, if not the whole of it is known... besides treating the subject in that way without any reference to general geometrical theories or without any attempt to make a 'Zusammen Gesetzung' of the whole mass of theorems one obtains, is very uninteresting work."[128] Fenwick, at the time Mathematical Master at the Royal Military Academy, Woolwich and co-editor of the *Mathematician*, ultimately never appeared in the *Journal*.[129]

[126]Thomas Weddle, "Demonstration of Pascal's Hexagramme," *Cambridge and Dublin Mathematical Journal* 3 (1848): 285-286 on p. 285.

[127]Thomas Weddle, "On the Different Published Demonstrations of 'Pascal's Hexagramme'," *Cambridge and Dublin Mathematical Journal* 4 (1849): 284-285. Pascal's theorem of the hexagram, and its dual, Brianchon's theorem, in fact received a lot of press in British journals during the 1830s and 1840s. See the case study on analytic geometry in chapter 7. In the *Journal*'s fourth and fifth volumes, Weddle, then Mathematical Master at the National Society's Training College, Battersea, considered analogues to Pascal's and Brianchon's theorems in space; Cayley, however, informed him that some of his results had been anticipated by Otto Hesse at the University of Königsberg. Michel Chasles had also earlier proven some of Weddle's results, but sent an encouraging letter to the mathematician. Thomas Weddle, "On the Theorems in Space Analogous to those of Pascal and Brianchon in a Plane," *Cambridge and Dublin Mathematical Journal* 4 (1849): 26-44; 5 (1850): 58-69; and 6 (1851): 114-135.

[128]Arthur Cayley to William Thomson, Kelvin Papers, Cambridge University Library, Add 7342, 8 February 1847.

[129]For more on this incident as well as Fenwick's work that appeared in the *Mathematician*, see Crilly, pp. 20-21. For an example of a substandard paper by the Edinburgh mathematician Andrew Bell that Thomson nevertheless felt bound to publish, see the case study on mathematical physics

In selecting papers for publication in the *Journal,* Thomson had to strike a delicate balance. Situated between the society journals on the one hand and the minor mathematical serials on the other, the *Journal* could not survive without a wide, paying readership, yet its editor and most dedicated supporters were committed to the pursuit of research mathematics. Some of these supporters, like Cayley, Boole, and Ellis, had cut their mathematical teeth on the *Journal*'s predecessor and were now contributing to it as established mathematicians.[130]

Crilly has argued that "[t]he range of articles indicates that it [the *Cambridge and Dublin Mathematical Journal*] was no longer a journal for undergraduates to try out ideas as the *C*[*ambridge*] *M*[*atheamtical*] *J*[*ournal*] had been... Consequently undergraduates of 1846 had lost a medium apart from a few exceptions."[131] Indeed, the average contributor to Thomson's journal was older than Gregory's authors. Of the 24 *Cambridge Mathematical Journal* authors for which birthdates were available, all but eight were less than 30 when making their first contributions; for the *Cambridge and Dublin,* 32 of the 59 contributors with available birthdates were over 30 when publishing their first article in the *Journal.*[132]

and mechanics in chapter 7.

[130]Crilly, p. 17. In fact, 13 contributors to the *Cambridge and Dublin Mathematical Journal* had also contributed to its predecessor.

[131]*Ibid.*

[132]Birthdate information was unavailable for two of the *Cambridge Mathematical Journal* contributors and six of the *Cambridge and Dublin* contributors. Since each of the *Cambridge Mathematical Journal*'s volumes ran over two-year periods (volume one ran from 1837 to 1839, and volume two ran from 1839 to 1841, for example), the middle date of this period was used to date an author at his first contribution (James Cockle, for example, was born in 1819 and made his first contribution to volume 2, so he is dated as 21). The average age for a first contribution to the *Cambridge Mathematical Journal* was 29.4 (without its oldest contributor, Gregory's former teacher, William Wallace, this average drops to 27.7). The same average for the *Cambridge and Dublin* was 32.8.

These older contributors had different conceptions about the kind of forum the *Cambridge and Dublin Mathematical Journal* represented. Stokes viewed the *Journal* as an educational venue but reserved his most important research for society journals such as the *Transactions of the Cambridge Philosophical Society.* His attitudes can be seen in his papers on Clairaut's theorem in geodesy.[133] Stokes wrote to Thomson that "I am writing a paper on Clairaut's Theorem for the Philosoph[l] [i.e. the *Transactions of the Cambridge Philosophical Society*], in which I introduce Laplace's Coeff[ts], but I propose to write another demonstration without Laplace's Coeff[ts] for the [*Cambridge and Dublin*] math[l] journal, for the sake of the men."[134] Cayley, on the other hand, was happy to publish remarkable research in the *Journal*; for example, it was there that he placed his discovery with George Salmon that 27 lines lie on a cubic surface.[135]

Thomson's *Journal,* unlike its predecessor, was not for students by students, nor was it completely for researchers by researchers. It was, instead, a mix of articles at differing levels by mathematicians with differing abilities. In trying to please

[133]This theorem used the gravity at the equator and poles of the earth in order to determine its ellipticity. For more on this theorem and the role of Stokes's proof of it in the Tripos, see chapter 7.

[134]G.G. Stokes to William Thomson, Kelvin Papers, Cambridge University Library, 29 March 1849, in David B. Wilson, ed., *The Correspondence Between Sir George Gabriel Stokes and Sir William Thomson, Baron Kelvin of Largs*, 2 vols. (Cambridge: University Press, 1990), 1: 70. Stokes published this paper for the men as G. G. Stokes, "On Attractions, and on Clairaut's Theorem," *Cambridge and Dublin Mathematical Journal* 4 (1849): 194-219. His paper to the Cambridge Philosophical Society was G.G. Stokes, "On the Variation of Gravity at the Surface of the Earth," *Transactions of the Cambridge Philosophical Society* 8(1849): 672-695. Ball gave the following definition of Laplace's coefficients: "If the co-ordinates of two points be (r, μ, ω) and (r', μ', ω'), and if $r' \nleq r$, then the reciprocal of the distance between them can be expanded in powers of r/r', and the respective coefficients are Laplace's coefficients. Their utility arises from the fact that every function of the co-ordinates of a point on the sphere can be expanded in a series of them." W. W. Rouse Ball, *A Short Account of the History of Mathematics*, 3rd ed. (London: Macmillan and Co., 1901), p. 432.

[135]Arthur Cayley, "On the Triple Tangent Planes of Surfaces of the Third Order," *Cambridge and Dublin Mathematical Journal* 4 (1849): 118-132. For more on this discovery, see chapter 7.

everyone, it seems that Thomson, in the end, did not please anyone; at least he did not please enough people to keep the *Journal* financially afloat. The *Cambridge and Dublin Mathematical Journal*, in fact, did not escape the financial worries that plagued many independent journals during the nineteenth century. By the third volume, the *Journal*'s publisher, Macmillan, Barclay & Macmillan (which would, by 1852, become Macmillan & Co.), warned readers of impending financial peril: "[t]he Publishers of the *Cambridge and Dublin Mathematical Journal* regret to have to announce that the sale is not sufficient to meet the expenses, when the Numbers are supplied through the booksellers and the usual trade allowance given. They therefore propose, after the completion of the present volume, to publish the *Journal* by *Annual Subscriptions, payable in advance*."[136] By 1850, Macmillan & Co. reported to Thomson that his *Journal* "is not only losing but increasing in loss every late number."[137] In an accounting by the publishers the next year, they told Thomson that "it is wonderful that it sh[oul]d so nearly cover its expenses. We sh[oul]d be glad if it did a little more."[138] They asked Thomson for his thoughts on increasing the *Journal*'s profitability and asked, "Is it getting more abtruse? Is it worth while to give away so many copies as we do?"[139] In fact, of the 9600 copies of the *Journal*'s first 26 numbers, 300 were given as presents.[140] Despite these measures as well as running

[136][Publishers' Notice], *Cambridge and Dublin Mathematical Journal* 3 (1848). Their emphasis. Besides its Cambridge publisher, Macmillan, Barclay, & Macmillan, the *Journal* also listed as secondary publishers George Bell in London and Hodges & Smith in Dublin.

[137]Macmillan & Co. to William Thomson, Kelvin Papers, Cambridge University Library, 18 May 1850.

[138]Macmillan & Co. to William Thomson, Kelvin Papers, Cambridge University Library, 30 October 1851.

[139]*Ibid.*

[140]The print run for the first 24 numbers was 500 per number; however, on six occasions, 500 copies

advertisements in the *Athenaeum*, the *Ladies' Diary*, the *Journal of Education*, and the *Philosophical Magazine*, the *Mathematical Journal* still ran at a loss: for the first 26 numbers and a reprint of the first volume of the *Cambridge Mathematical Journal*, the income amounted to £882 while the cost stood at £920.[141]

A few months before Macmillan's uninspiring accounting report, Thomson had written to Stokes that he was "beginning to be anxious to retire" from the editorship of the *Journal*.[142] Despite Ellis's earlier prediction that Thomson would have the longer residence in Cambridge, Thomson had been elected to the Chair of Natural Philosophy in Glasgow after only one year as editor of the *Journal*. After operating the *Journal* from a distance for six years, Thomson was ready to pass his editorial torch. In his attempt to convince Stokes to accept the editorship, Thomson explained that "I have found the duties not on the whole onerous, even although I have been away from Cambridge so much, and I have always found them very pleasant. My mathematical friends have always been most kind in helping me by giving me reports on papers, and I have never once found it necessary to wade through a paper on a subject that was at all out of my way, as you, and others have formed a sufficient council to enable me always without difficulty to find a willing referee."[143] Thomson, however, did not spare Stokes from the difficulties that might await him as an editor:

total were made of two subsequent numbers. The print run for the 25th and the 26th numbers was decreased to 300 copies each.

[141] Macmillan & Co. Balance Sheet Midsummer 1851, Kelvin Papers, Cambridge University Library. The sterling amounts have been rounded.

[142] William Thomson to G.G. Stokes, Stokes Papers, Cambridge University Library, Add 7656, 21 April 1851.

[143] *Ibid.*

"I ought to let you know that I am always getting complaints...from the publishers and that the existence of the Journal is a perpetual struggle."[144]

Stokes declined the editorship, but Thomson was able to recruit the assistance of the 1851 Senior Wrangler Norman Ferrers. While the eighth volume carried both of the editors' names, an 1853 letter from Ferrers to Thomson indicates that the senior editor's presence on the title page was mainly for appearances: "I am very glad to hear that the Macmillans have requested you to allow your name to remain as Editor of the Journal as such an arrangement cannot but be most beneficial."[145] Ferrers appeared as the sole editor for the journal's ninth volume, which would be its last. Macmillan & Co. had suggested to Ferrers in 1852 that the *Journal* be terminated and begun again under a new title.[146] By 1854, the publishers' "strong wish to abandon" the *Journal* incited Ferrers to take action.[147] He discussed with Thomson the plan of looking for a new publisher: "Sylvester has often told me that he is quite sure the publishers of the Philosophical Magazine [Taylor & Francis] would be glad to take it up and would advertise it extensively and energetically." Reminiscent of Macmillan & Co.'s suggestion, Ferrers proposed that if finding a new publisher became necessary, then "perhaps some slight modification of the name of the Journal might be desirable. I can imagine how Cayley, and how particularly Sylvester would

[144] *Ibid.*
[145] N.M Ferrers to William Thomson, Kelvin Papers, Cambridge University Library, Add 7342, 26 Jan. 1853.
[146] N.M Ferrers to William Thomson, Kelvin Papers, Cambridge University Library, Add 7342, 30 June 1852.
[147] N.M Ferrers to William Thomson, Kelvin Papers, Cambridge University Library, Add 7342, 20 Feb. 1854.

receive the suggestion of the Journal stopping."[148]

Sylvester and Cayley reacted to the termination of the *Cambridge and Dublin Mathematical Journal* by aiding Ferrers in the foundation of the *Quarterly Journal of Pure and Applied Mathematics* in 1855. With Ferrers and Sylvester at the helm of an editorial team including Cayley, Stokes, and Charles Hermite, the *Quarterly Journal* declined Macmillan & Co. for a London publisher and left its predecessors' university focus for wider, international goals.[149]

Just before the debut of the *Quarterly Journal,* Ferrers wrote to Thomson that "[y]ou will be glad to hear that we have a very varied table of contents for our first number."[150] In fact, the *Quarterly Journal* continued to offer an assortment of pure and applied mathematics through the nineteenth century (see Table 4B).[151] For 1855 through 1867, analytic geometry and algebra were common subjects for the *Journal,* accounting for over 50% of its pages. While the shares of both areas dropped for 1868 to 1900, they still represented over one-third of *Journal*'s pages for this period. Activity in mechanics in the *Journal* increased to 13.5% during the second period, and the area represents the third most popular area for the entire nineteenth-century existence of the *Journal.*[152] Despite this interest in applied mathematical topics, the

[148] *Ibid.*

[149] For a discussion of the *Quarterly Journal*'s efforts to enter the international arena, see chapter 6. The publisher chosen by the editors was John W. Parker, who printed the *Journal*'s first six volumes. Longmans & Co. (with various alterations of title) published the remaining nineteenth-century volumes of the journal.

[150] N.M Ferrers to William Thomson, Kelvin Papers, Cambridge University Library, Add 7342, 27 Mar. 1855.

[151] As in table 4A, the percentages for 1868-1900 for table 4B are based on the categorizations of the *Jahrbuch über die Fortschritte der Mathematik.* For more on the *Jahrbuch* categorization and periodization of this table, see chapter 7.

[152] The areas of algebra, analytic geometry, and mechanics form three of the five most popular

Journal remained dominated by pure mathematics during the nineteenth century.

Table 4B: The Mathematical Content of the
Quarterly Journal of Pure and Applied Mathematics, 1855-1900

Category	1855-1867		1868-1900		Total	
	#†	pg. %	#	pg. %	#	pg. %
Other	13	0.7%	0	0.0%	13	0.2%
Algebra	77	20.6%	89	13.9%	166	15.7%
Analytic Geometry	189	33.0%	174	22.6 %	363	25.4%
Combinatorics & Probability	8	2.0%	9	0.8%	17	1.1%
Differential & Integral Calculus	39	9.8%	79	10.7%	118	10.4%
Function Theory	20	5.6%	53	9.7%	73	8.6%
Geodesy & Astronomy	20	4.0%	8	0.5%	28	1.5%
Higher & Secondary Arithmetic§	22	2.9%	37	6.4%	59	5.5%
History and Philosophy	2	0.4%	1	0.0%	3	0.1%
Math'l. Physics	26	4.9%	55	9.3%	81	8.1%
Mechanics	53	8.7%	104	13.5%	157	12.2%
Pure, Elementary, & Synthetic Geom.	34	3.1%	61	6.7%	95	5.7%
Series	18	4.2%	29	6.1%	47	5.6%

† "#" denotes the number of articles, "pg. %" denotes the percentage of mathematical pages, rounded to the nearest 0.1%

§ "Higher and Secondary Arithmetic" is a *Jahrbuch* category roughly equivalent to number theory. See chapter 7.

The accomplishments of the 213 nineteenth-century contributors to the *Quarterly Journal* illustrate the high caliber of authors which the editorial team was able to attract. Six of these contributors received the Sylvester Medal, a mathematical award first given by the Royal Society in 1901 in honor of J.J. Sylvester.[153] Likewise, 12 of the first 17 recipients of the De Morgan Medal, awarded by the London Mathematical Society, published in the *Quarterly Journal*.[154] Besides award winners, members of the London Mathematical Society were enthusiastic supporters of the *Journal*,

areas for a wide sample of journals considered in chapter 7. See chapter 7 for overviews and case studies of these areas.

[153]These six winners were among the first 13 award recipients for 1901 through 1937.

[154]These first 17 medals were awarded for the years 1884 through 1932.

accounting for 90 (or 42.3%) of its nineteenth-century contributors and over half of its contributions; 21 of these members also served as the Society's President.[155] Thus, many of those building and sustaining the first major mathematical society in Britain also helped to support the mathematical framework of the *Quarterly Journal*.

At the heart of this journalistic enterprise, a star-studded editorial team directed the *Quarterly Journal* throughout most of the nineteenth century. Hermite's collaboration in this otherwise British editorial effort can be seen as an extension of the close mathematical relationship he shared with Cayley and Sylvester. Hermite, at the École Polytechinque, joined the two British mathematicians in their quest to understand and characterize invariants and covariants. He had repeatedly contributed articles to the *Cambridge and Dublin Mathematical Journal*, including one that announced his discovery of a law of reciprocity for invariants and covariants.[156] Not surprisingly, he joined his two invariant theory colleagues in their effort to resurrect the *Journal* and continued to be an active member of the British mathematical publication community for decades.

By 1887, the *Quarterly Journal* had lost Sylvester, Hermite, and Stokes and had gained the two Trinity College, Cambridge fellows, Andrew Forsyth and James Glaisher.[157] Forsyth had graduated as the Senior Wrangler and First Smith's Prize-

[155]These 21 presidents of the London Mathematical Society were among the first 35 presidents for the years 1865 through 1933. The 90 members mentioned above include four honorary members of the London Mathematical Society.

[156]For more on this law and Hermite's other contributions, see chapter 6.

[157]From 1884 to 1895, Forsyth helped edit the *Journal*. Hall, p. 88. Glaisher joined the editorial team in 1879. June Barrow-Green, "'A Corrective to the Spirit of too Exclusively Pure Mathematics': Robert Smith (1689-1768) and his Prizes at Cambridge University," *Annals of Science* 56 (1999): 271-316 on p. 299.

man for 1881, and by the time he joined the *Quarterly Journal* as an editor, he was well on his way to what was considered at the time a "pyrotechnic career."[158] By 1883, he had accepted a Trinity lectureship and was about to write his first book. At the end of his tenure as a *Quarterly Journal* editor in 1895, Forsyth was regarded as a Cambridge sensation. His *Theory of Functions of a Complex Variable* "burst in 1893 with the splendour of a revelation"[159] and has been called "the book that brought modern analysis to England."[160] In 1895, Forsyth succeeded Cayley as Sadlerian Professor of Pure Mathematics. Soon, however, his 1893 book received criticism from abroad for its lack of rigor,[161] and Forsyth experienced an "unparalleled eclipse" as a mathematician: "it was his own achievement to bring to Cambridge the mathematics in which he could not excel and the cosmopolitan standards by which he was to be so harshly judged."[162]

Glaisher, the other new addition to the *Quarterly Journal*'s editorial staff, had a more measured career at Cambridge. As a lifelong unmarried Fellow in residence, Glaisher became very active in British scientific societies and periodicals.[163] Before his position with the *Quarterly Journal*, Glaisher had edited the *Messenger of Mathematics* for over a decade and had been its sole director since approximately 1877.[164]

[158] E.H. Neville, "Andrew Russell Forsyth," *Journal of the London Mathematical Society* 17 (1942): 237-256 on pp. 239, 241.
[159] *Ibid.*, p. 245.
[160] Gray, p. 91.
[161] *Ibid.*
[162] Neville, p. 256.
[163] Recall the discussion in chapter 2 regarding Glaisher's work in British scientific societies.
[164] In his article on Glaisher and the *Messenger*, Hardy gives the date the beginning of Glaisher's sole editorship as "1877 (?8)." Godfrey Harold Hardy, "Dr. Glaisher and the 'Messenger of Mathematics'," *Messenger of Mathematics* 58 (1929): 159-160 on p. 159.

By the 28th volume of the *Quarterly Journal* (1895-1896), he was again the only one left to direct the enterprise, and he continued to do so until his death in 1928. Thus, what began as a team effort among the stars of British mathematics of the second half of the nineteenth century eventually became the project of one indefatigable Cambridge Fellow.

In his many years at Cambridge, Glaisher witnessed significant changes in an examination system that sought to increase the initiative for students to enter into mathematical research. While it was responsible for much of Cambridge's mathematical flavor, the Tripos examination had, as noted above, tightly circumscribed the mathematical topics studied by students.

In 1867, the Board of Mathematical Studies at Cambridge had come up with a new scheme to allow the subject areas to broaden. The plan, accepted a year later, offered students a wide variety of topics but allowed them to focus on areas of interest. However, "it was found that, unless the questions were made extremely difficult, more marks could be obtained by reading superficially all the subjects... than by attaining real proficiency in a few of the higher ones; and the best men of the year were tempted, not to say compelled, to extend their reading as widely as possible over the book-work of the whole range of subjects. Thus, with respect to the main object which the framers of the scheme had in view, it was a complete failure."[165] In 1878, the Board passed a new reform aimed at easing the competitive nature of the Tripos. The first component of the examination retained the traditional ordering of candidates

[165]Glaisher, "The Mathematical Tripos," p. 23.

by merit. However, the second component, open only to wranglers, divided the candidates by merit into three classes listed only in alphabetical order.[166] Without the stress of the order of merit, the last part of the examination could involve detailed questions on specialized subjects.[167] Glaisher hailed this new reform as a positive development: "no longer is the wise and thoughtful student hopelessly distanced in the Tripos race by his quick and ready rival."[168] In his view, while the order of merit had served "as a stimulus to industry, an encouragement to thoroughness in mathematical study, and a paramount influence in regulating elections to fellowships at colleges where no independent examination existed — it has yet been in recent years a deadly enemy to the spread of research and the advance of our science."[169]

Besides the Tripos, the Smith's Prizes also experienced major reforms in the last quarter of the nineteenth century. Created by the bequest of Trinity College, Cambridge Master Robert Smith in 1798, these two prizes were to be awarded annually to bachelors of arts for ability in mathematics and natural philosophy.[170] Until 1883, the Prizemen, like the wranglers, were selected by examination. The Smith's Prizes examination questions generally encouraged original thinking rather than the memorization and coaching strategies used by many of those taking the Tripos and maintained a special emphasis on applied mathematics.[171] However, after reforms in 1868

[166] *Ibid.*, pp. 25-26.
[167] *Ibid.*, p. 26.
[168] *Ibid.*, p. 31.
[169] *Ibid.*, p. 32. By 1906, the order of merit was completely eliminated from the Tripos, and the candidates were last ranked in 1909. Barrow-Green, p. 300.
[170] Barrow-Green, p. 272.
[171] *Ibid.* In fact, these questions were sometimes based on new research. For example, Stokes presented "Stokes' Theorem" in potential theory for the first time in print in an 1854 Smith's Prize examination. *Ibid.*, p. 285.

extended the range of subjects covered by the Tripos, there arose concerns about how to differentiate the two examinations. The introduction of dissertations as a means to select new fellows at Trinity College in 1872 provided reformers with an example.[172] By 1883, the essay format was adopted for the adjudication of the Smith's Prizes and the "possibility of properly organized postgraduate research" became a reality.[173]

While mathematicians at Cambridge altered their examination system in order to prepare their graduates to conduct research competitive at an international level, the *Cambridge Mathematical Journal* had matured through two reincarnations towards a more international contributorship and original research. However, the result of this maturation, the *Quarterly Journal*, left room for a mathematical journal that catered exclusively to the needs of British undergraduates.

The *Oxford, Cambridge, and Dublin Messenger of Mathematics*: A New Publication Venue for Students

Like the *Cambridge Mathematical Journal* before it, the *Oxford, Cambridge, and Dublin Messenger of Mathematics* was "a journal supported by junior mathematical students."[174] The "board of editors composed of members of the three universities"[175] were either current students or recent graduates at the journal's launching. While Oxford and TCD were represented among the *Messenger*'s editors, four of the six men directing the journal had firm Cambridge ties. William Whitworth and Charles Taylor, both of St. John's College, Cambridge, graduated as 16th and Ninth Wran-

[172] *Ibid.*, pp. 290, 299.
[173] *Ibid.*, p. 308.
[174] [Title page], *Oxford, Cambridge, and Dublin Messenger of Mathematics* 1 (1862). This statement appeared on the title page of each of this journal's five volumes.
[175] *Ibid.*

glers, respectively, in 1862; a few years later, both men began extended fellowships.[176] The other two Cambridge editors matriculated at Cambridge from other British universities. Henry John Purkiss finished an MA at the University of London before moving to Trinity College, Cambridge, from which he graduated as Senior Wrangler and First Smith's Prizeman in 1864.[177] James McDowell, of Pembroke College, Cambridge, graduated with Purkiss as Seventeenth Wrangler, but he had earlier won the first silver medal in mathematics while a student at TCD.[178]

John Casey, unlike McDowell, had studied exclusively at TCD and graduated with his BA in 1862. Besides his work with the *Messenger*, Casey was for several years a Dublin correspondent for the review periodical, the *Jahrbuch über die Fortschritte der Mathematik*. In addition, he carried on an active correspondence with mathematicians from abroad, "all of whom held Casey's work in high esteem."[179]

The final editor on this board, Henry William Challis, was the only one who had Oxford ties. Through his editorship of the *Messenger*, Challis studied at Merton College, Oxford and received his BA in 1864 and his MA in 1871.[180] While Cambridge students were immersed in a competitive environment spawned by the Tripos, honors students at Oxford were not ranked, and not everyone was expected to engage in mathematical study. Although university scholarships established in 1831 resembled

[176]Venn, s.v. "Whitworth, William Allen" and "Taylor, Charles." Taylor became the Master of St. John's in 1881.

[177]Frederic Boase, *Modern English Biography* (London: Frank Cass & Co. Ltd., 1965), s.v. "Purkiss, Henry John."

[178]Boase, s.v. "McDowell, James."

[179]"John Casey," *Proceedings of the Royal Society of London* 49 (1890-1891): xxiv-xxv on p. xxv.

[180]Joseph Foster, *Alumni Oxonienses: The Members of the University of Oxford, 1715-1886: Their Parentage, Birthplace, and Year of Birth, with a Record of Their Degrees* (Oxford and London: Parker and Co., 1887-1888), s.v. "Challis, Henry William."

the Smith's Prizes, they did not play as major a role as their Cambridge counterparts.[181] Nevertheless, with Challis, Oxford mathematicians joined the university mathematical journalistic tradition, and in the twentieth century, they provided a substantial center for this publication venue.

As students and recent graduates of Oxford, Cambridge, and TCD, the editors perceived that the mathematicians of these three universities "are more and more widely separating in style and selection of subjects; and this bids fair to be a serious evil. Let us have an English school of mathematics by all means, but sub-divisions in that school are simply an evil."[182] Other attitudes reflected by the editors in their addresses to their readers are reminiscent of Babbage's dissatisfaction with the focus on examinations at Cambridge. They complained that tutors advised students to "'Shut your eyes and write down your equations'... The operation of solving these equations is of entirely second-rate value; and yet it occupies — and the limited range of low subjects makes it necessary that it should occupy — by far the most important place in a mathematical education."[183]

In order to improve this situation, the editors founded their journal to "induce such students to attempt original investigation in their favourite branches of mathematics."[184] However, as recent graduates, they recognized that their target audience

[181] John Fauvel, "800 Years of Mathematical Traditions," in *Oxford Figures: 800 Years of the Mathematical Sciences*, ed. John Fauvel, Raymond Flood, and Robin Wilson (Oxford: University Press, 2000), pp. 1-27 on p. 25.
[182] *Ibid.*, p. 4.
[183] "Introduction," *Oxford, Cambridge, and Dublin Messenger of Mathematics* 1 (1862): 1-4 on pp. 1-2.
[184] *Ibid.*, p. 2.

needed an incentive to contribute to the journal, and they promised that "the distinctness of conception, and the exercise of imagination required for such work will be found to react on themselves with profit in University examinations."[185] The directors of the new journal also wished to provide students with memoirs tracing the development of mathematical subjects and asked "mathematicians of higher standing [to] ...furnish us with papers on these subjects for the benefit of their younger brethren."[186] Besides historical developments of mathematical subjects, the editors solicited from "some competent person" reviews of the "state of the science and the problems on which our professors at home and abroad are engaged," such as "this all powerful new Calculus of Quaternions... We would most earnestly solicit information on such subjects as these; for which no magazine that previously existed, is at all adapted."[187]

As subsequent volumes of the *Messenger* appeared, several of the plans of the journal's editors materialized. In the "all powerful" area of quaternions, there appeared the three-part article "Quaternions" by Peter Guthrie Tait, Professor of Physics at the University of Edinburgh, and "Quaternions, or the Doctrine of Vectors. Elementary Illustrations," by Professor of Mathematics at Edinburgh.[188] In the arena of student preparation, Arthur Cayley provided several papers on the Smith's Prize examination

[185] *Ibid.*
[186] *Ibid.*, pp. 2-3.
[187] *Ibid.*, pp. 3-4.
[188] Peter Guthrie Tait, "Quaternions," *Oxford, Cambridge and Dublin Messenger of Mathematics* 1 (1862): 78-91, 140-156, 203-219; and Philip Kelland, "Quaternions, or the Doctrine of Vectors. Elementary Illustrations," *Oxford, Cambridge and Dublin Messenger of Mathematics* 2 (1864): 136-167. As the late-nineteenth-century champion of quaternions, Tait was trying to get young converts by writing in the *Messenger.*

and the Tripos.[189] Besides directing the *Messenger*, the editors themselves provided almost one-quarter of the articles for their journal.

As Table 4C shows, geometry dominated the *Oxford, Cambridge, and Dublin Messenger of Mathematics*, accounting for over half of its pages. Besides geometry, articles on applied mathematics were also prominent in the *Messenger*, occupying over one-fifth of its pages for 1862 to 1870. These two areas were mainstays of the Cambridge mathematical curriculum, a fact that reflects the journal's student focus.[190]

Table 4C: The Mathematical Content of the *Oxford, Cambridge, and Dublin Messenger of Mathematics*, 1862-1870 and the *Messenger of Mathematics*, 1871-1900

Category	1862-1870		1871-1900		1871-1900 w/o Glaisher	
	#†	pg. %	#	pg. %	#	pg. %
Other	3	0.5%	-	-	-	-
Algebra	16	9.7%	141	10.6%	137	12.0%
Analytic Geometry	96	32.9%	162	10.7%	161	12.6%
Combinatorics & Probability	9	2.6%	22	1.3%	22	1.5%
Differential & Integral Calculus	10	4.2%	151	12.6%	130	12.5%
Function Theory	5	4.3%	162	14.8%	115	20.3%
Geodesy & Astronomy	7	1.1%	9	0.5%	9	0.6%
Higher & Secondary Arithmetic§	16	3.1%	92	10.3%	92	12.1%
History and Philosophy	-	-	13	1.4%	10	1.0%
Math'l. Physics	15	4.1%	48	4.5%	48	5.3%
Mechanics	37	15.9%	106	8.3%	106	9.7%
Pure, Elementary, & Synthetic Geom.	54	17.5%	128	6.9%	123	7.7%
Series	7	4.1%	105	10.6%	65	4.6%

† "#" denotes the number of articles, "pg. %" denotes the percentage of mathematical pages.

§ "Higher and Secondary Arithmetic" is a *Jahrbuch* category roughly equivalent to number theory. See chapter 7.

[189] Arthur Cayley, "A 'Smith's Prize' Paper," *Oxford, Cambridge and Dublin Messenger of Mathematics* 4 (1868): 201-225, 5 (1871): 40-64, 182-203; and Arthur Cayley, "Solution of a Senate-House Problem," *Oxford, Cambridge and Dublin Messenger of Mathematics* 5 (1871): 24-26.

[190] For more on the place of these areas in the Cambridge mathematical curriculum, see chapter 7.

Although it was aimed at British university students, the *Oxford, Cambridge, and Dublin Messenger of Mathematics* received notice abroad. A review of the journal's first volume in the *Nouvelles annales de mathématique*, a "journal of the candidates at the École polytechnique and the École normale"[191] provided commentary on both the *Messenger* and the British educational system: "[w]e recommend this journal to those of our readers who would like to learn about the methods adopted in England for teaching science. The direction given towards scientific studies in this country differs greatly from that which we follow in France; each one has its good attributes, and thus it is useful to know both."[192]

By the fifth volume of the *Oxford, Cambridge, and Dublin Messenger of Mathematics*, only Whitworth, Taylor, and William Turnbull,[193] all of Cambridge, remained on the editorial staff. At the end of this volume, in 1871, a new initiative supported by Whitworth, Taylor, and three new editors cut the university ties of the journal. By naming the new series of their journal the *Messenger of Mathematics*, the editors hoped to "appeal directly to the mathematical world at large, and to remove from their title-page any words which might be supposed to limit the sphere of usefulness

[191]The subtitle of the journal was "journal des candidats aux Écoles polytechnique et normale."

[192]"The Oxford, Cambridge and Dublin Messenger of Mathematics," *Nouvelles annales de mathématique*, ser. 2, 2 (1863): 191-192 on p. 191. "Nous recommandons ce journal à ceux de nos lecteurs qui voudraient prendre connaissance des méthodes adoptées pour l'enseignement des sciences, en Angleterre. La direction donnée aux études scientifiques, dans ce pays, diffère beaucoup de celle que nous suivons en France; chacune d'elles a son bon côté, et c'est pourquoi il est utile de les connaître toutes deux."

[193]William Turnbull, a Trinity College, Cambridge student who graduated second to Purkiss in the Tripos and Smith's Prize examination in 1864, replaced Purkiss on the *Messenger*'s editorial board after the latter's early death by drowning in the River Cam in 1865. *Modern English Biography* s.v. "Purkiss, Henry John."

of the Messenger."[194]

While the journal's title lost its collegiate tone, the editorial board remained well within the educational network of Cambridge and Oxford. Richard Pendlebury, one of the new editors, had just graduated as the Senior Wrangler and First Smith's Prizeman for 1870 and subsequently was elected to a fellowship at St. John's College, Cambridge that he would hold for 33 years. Another addition to the *Messenger*'s board, William Lewis, similarly had just accepted a fellowship at Oriel College, Oxford, which he would hold for 57 years. In 1874, Lewis studied crystallography at Cambridge under the Chair of Mineralogy, William Hallowes Miller. Seven years later, he succeeded his teacher and held this post at Cambridge for 45 years.[195]

James Glaisher, the last addition to this editorial team, graduated from Cambridge as Second Wrangler in 1871 and obtained a fellowship at Trinity College, where he resided the rest of his life.[196] As with the *Quarterly Journal*, Glaisher soon became the sole director of the *Messenger of Mathematics*; by the end of the 1870s, he alone was left to lead this journal into the twentieth century.[197]

Hardy characterized Glaisher as the "last of the old school of mathematical editors, the men, who, like Liouville, contrived to run mathematical journals practically unaided."[198] Hardy placed Glaisher in the "old school" because he felt that the breadth

[194] "Advertisement," *Messenger of Mathematics* 1 (1871): iii-iv on p.iii.
[195] "William James Lewis — 1847-1926," *Proceedings of the Royal Society of London*, ser. A, 111 (1926): xliv-xlviii on p. xlv.
[196] Andrew Russell Forsyth, "James Whitbread Lee Glaisher," *Journal of the London Mathematical Society* 4 (1929): 101-112 on p. 101.
[197] Hardy, p. 159. While the names of Whitworth, Taylor, and Pendlebury appear on the title page of the *Messenger* as late as its eighth volume (May 1878—April 1879), Hardy states that Glaisher was the lone editor of the journal from 1877 or 1878.
[198] *Ibid.*, p. 159.

and depth of twentieth-century mathematics rendered "more and more thankless" the job of an editor without a supporting panel of experts.[199] While admiring the duty that Glaisher performed, Hardy predicted that "it is hardly likely that the experiment will be repeated."[200] In fact, even during the nineteenth century, effectively editing and applying strict standards to a journal entirely alone became more and more impossible. In his position, Glaisher could, and did, "publish his own investigations [in the journal] as he pleased."[201] His contributions to the *Messenger* spanned the first through the 57th volumes and amounted to 179 of his almost 400 papers. In Forsyth's opinion, Glaisher was a "stimulus to others rather than a pioneer whose manifold investigations can be acclaimed as memorable."[202] Hardy believed that Glaisher, while prolific, wrote papers "of very uneven quality, and he was 'old fashioned' in a sense which is most unusual now; but the best of his work is really good."[203] In calling his work old fashioned, Hardy cited the example of Glaisher's arithmetical research; it belonged neither to classical number theory nor to the analytic approach to field, in which the "general principles of function theory" are applied to arithmetical questions. Instead, Glaisher considered *specific* functions in his arithmetical research. In Hardy's opinion, Glaisher's application of specific elliptic functions to arithmetic, while outmoded, represented his highest quality work.[204] Forsyth also considered much of Glaisher's work outdated, calling the editor the master of "all this lore" on

[199] *Ibid.*
[200] *Ibid.*
[201] Forsyth, p. 111.
[202] *Ibid.*, p. 112.
[203] Hardy, p. 160.
[204] *Ibid.*

the British approach to differential equations actively pursued during the first half of the nineteenth century.[205]

We can see the effect that Glaisher's contributions had on the mathematical content of the *Messenger* in Table 4C. His articles had a marked effect on the number of articles and the percentage of pages devoted to series. With him, the area was the subject of 105 articles from 1871 to 1900 and occupied 10.5% of the pages; without him, the number of articles fell to 65 and the page percentage dropped to 4.6%. Forsyth described Glaisher's papers on series as coming "in endless profusion, dealing with...ever additional weird series having special functional numbers for their coefficients, with new and strange identities, and with new results relating to series that could be expressed in known non-algebraical numbers or constituting fresh constants."[206]

Eliminating Glaisher's contributions caused the pages occupied by function theory to drop by over 7%. Even without Glaisher's 47 contributions on function theory, this area was the one of the most popular among contributors to the *Messenger* from 1871 to 1900. Cayley, like Glaisher, bolstered the share of the area in the journal with 32 contributions occupying almost 2% of the *Messenger*'s pages. Algebra and number theory[207] were areas on which Glaisher published little in the *Messenger* but that still enjoyed high levels of activity. Analytic geometry, and pure, elementary, and synthetic

[205]Forsyth, p. 110. For more on this British approach to differential equations, related to the calculus of operations, see chapter 7.
[206]*Ibid.*, p. 110.
[207]The *Jahrbuch* classified Glaisher's research on the application of elliptic functions to arithmetic as "Function Theory" instead of "Number Theory."

geometry also shared this distinction, but they had been much more actively covered in the *Messenger*'s predecessor. Applied mathematical coverage also fell considerably after 1871, dropping from over one-fifth to about one-eight of the journal pages. This drop may have also indicated the editorial power of Glaisher, who, outside of his interests in astronomy, was primarily a pure mathematician.[208]

With Glaisher as the only editorial gatekeeper, the *Messenger* formed a conducive publication venue for young mathematicians. Of those who had made their mathematical début in the *Messenger*, Hardy listed Henry Baker, William Burnside, Edwin Bailey Elliott, and Forsyth, all of whom would serve as President of the London Mathematical Society.[209] In fact, the mean age at which contributors published their first article in the *Messenger* was about 35, and about 40% of these contributors were in their twenties or teens when they first contributed.[210]

Besides editing and being one of the major contributors of both the *Messenger of Mathematics* and the *Quarterly Journal*,[211] Glaisher was also the financial foundation for these journals during their later years.[212] After Glaisher's death on December 7, 1928 at the age of 80, the energy he gave to both journals could not be sustained

[208]The coverage of subjects in the articles in the *Messenger* reflects to some extent the general trends for the nineteenth-century British scientific journals considered in chapter 7. While function theory did not enjoy the same degree of popularity in these journals that it did in the *Messenger*, the number of articles on this area in these journals markedly increased after 1867. Number theory also increased in popularity for these journals, and the coverage of analytic geometry decreased. See tables 7B and 7C.

[209]Hardy, pp. 159-160. The dates for these mathematicians, as well as the year of the volume in which their first contributions to the *Messenger* were made are: Baker (1866-1956) vol. 19 (1889); Burnside (1852-1927) vol. 12 (1882); Elliott (1851-1937); vol. 6 (1876); and Forsyth (1858-1942) vol. 9 (1879).

[210]The birthdates for 25 of the 200 contributors to the *Messenger* have not been found.

[211]Glaisher's nineteenth-century contributions alone to the *Quarterly Journal* amount to 58.

[212]*The Dictionary of National Biography*, s.v. "Glaisher, James Whitbread Lee."

by his successors. As a result, the *Messenger* was absorbed into a new series of the *Quarterly Journal* centered at Oxford.[213] Hardy's final description of the *Messenger* mourns the passing of a journalistic tradition: "[t]he *Messenger* was of course always a 'minor' journal;... [i]t occupied a comparatively humble position in the mathematical world, but a useful, individual, and honourable position, and we must all regret its extinction even if we accept it as inevitable."[214]

Conclusion

Grattan-Guinness has described nineteenth-century Cambridge "as an educational centre and as a forum for research activity and publication, the center of gravity for a partly scattered collection of mass points."[215] Indeed, the nineteenth-century journalistic endeavors of Cambridge students and graduates reached out to the "mass points" of TCD and Oxford as well as to mathematicians at other institutions in Britain and abroad.

Collectively and individually, mathematicians at Cambridge and Dublin felt an obligation to provide British university students with a forum in which to publish and learn mathematics. Examinations provided the impetus for much of the mathematical focus at these two institutions, and the journals of their students reflected this influence. The directors of these periodicals were strongly compelled to encourage original research rather than the problem-solving and memorization techniques

[213]The first volume of this new series appeared in 1930. Its first editors were the Oxford mathematicians, Theodore Chaundy, William Ferrar, and Edgar Poole, with the assistance of Arthur Dixon, Edwin Bailey Elliott, Hardy, Augustus Love, Edward Milne, F.B. Pidduck, and Edward Titchmarsh, also all from Oxford. With this team, the journal "went from strength to strength, bolstering along the way Oxford's research reputation within the international mathematics community." Fauvel, p. 16.

[214]Hardy, p. 160.

[215]Grattan-Guinness, p. 108.

encouraged by examinations. However, since much of their readership placed a high priority on preparing for and passing these examinations, the journals were often circumscribed by the demands of tests.

Both the *Cambridge Mathematical Journal* and the *Oxford, Cambridge, and Dublin Messenger of Mathematics* eventually moved away from their initial university focus and tried to pursue a broader profile of readers and contributors. While this change could reflect an earnest desire by the editors to reach out to the wider mathematical world, it could also represent a marketing decision made in the face of unfavorable sales. Nineteenth-century British mathematical periodicals, even those born in a mathematically active university atmosphere, always faced financial strain, and the job of editor of one of these enterprises was taken on as a labor of love rather than as a means to fame and fortune. Both the directors and contributors of these journals formed a devoted and active component of the British mathematical publication community.

Chapter 5: Domestic Members of the Nineteenth-Century British Mathematical Publication Community

Prosopography as a Tool for Investigating the Domestic Members of the Publication Community

In addition to the analysis of the structure, operation, goals, foundations, and failures of journals presented in the previous chapters, a profile of the journals' contributors further sharpens the picture of the nineteenth-century British mathematical publication community. This chapter thus turns to the domestic contributors, a group forming the majority, but not the totality,[1] of the publication community.

In their discussion of historical methods for the investigation of the British scientific community from 1700 to 1900, Steven Shapin and Arnold Thackray warned against focusing solely on the lives of renowned scientists: "[w]hat we *cannot* do is start with names known to us through their science; first we must find out who published science, then assess the intellectual and cultural significance of their association with the enterprise of natural knowledge."[2] Following their stricture, then, the names of domestic mathematical contributors here have come from a systematic review of the nineteenth-century contents of nine British scientific journals, including general and specialized periodicals supported by societies or commercial interests.[3] This has

[1]See chapter 6 for a profile of the international members of the nineteenth-century British mathematical publication community.

[2]Steven Shapin and Arnold Thackray, "Prosopography as a Research Tool in History of Science: The British Scientific Community 1700-1900," *History of Science* 12 (1974): 1-28 on p. 14. Emphasis theirs.

[3]This sample consists of all nineteenth-century volumes of British Association for the Advancement of Science *Report* (1831-present); Cambridge Philosophical Society *Transactions* (1822-1928); Manchester Literary and Philosophical Society *Memoirs* (1785-1887), *Proceedings* (1857-1887), *Memoirs and Proceedings* (1888-present); Royal Irish Academy *Transactions* (1787-1907); Royal Society of Edinburgh *Transactions* (1783-present); Royal Society of London *Philosophical Transactions*

yielded over 850 British mathematical contributors, and prosopography, or collective biography, has served as a tool for better understanding their education, career paths, and scientific society involvement.

Information about the training, occupations, and society activity of this group has come from a number of biographical dictionaries, alumni directories, and society membership lists.[4] These sources used within this mathematical context fit well the parameters Lawrence Stone set in his survey of the use of prosopography in historical studies: "the method works best when it is applied to easily defined and fairly small groups over a limited period of not much more than a hundred years, when the data is drawn from a very wide variety of sources which complement and enrich each other, and when the study is directed to solving a specific problem."[5] Moreover,

(1665-present), *Proceedings* (1832-present); Edinburgh Mathematical Society *Proceedings* (1883-present); London Mathematical Society *Proceedings* (1865-present); Royal Astronomical Society *Memoirs* (1822-present), *Monthly Notices* (1827-present); *Philosophical Magazine* (1798-present); *Cambridge Mathematical Journal* (1837-1845); *Cambridge and Dublin Mathematical Journal* (1846-1854); *Leybourne's Mathematical Repository* (1806-1835); *Oxford, Cambridge, and Dublin Messenger of Mathematics* (1862-1871); *Messenger of Mathematics* (1871-1929); and *Quarterly Journal of Pure and Applied Mathematics*(1855-1927).

[4]The sources consulted for this prosopography are *A Catalogue of the Graduates in the Faculties of Arts, Divinity, and Law of the University of Edinburgh since its Foundation*, (Edinburgh: Neill and Co., 1858); *Alphabetical List of Graduates of the University of Edinburgh from 1859 to 1888* (Edinburgh: J. Thin, 1889); William Innes Addison, *A Roll of the Graduates of the University of Glasgow, from 31st December, 1727 to 31st December, 1897, with Short Biographical Notes*, (Glasgow: MacLehose, 1898); George Dames Burtchaeli, Thomas Ulick Sadleir, ed., *Alumni Dublinenses*, (Dublin: Alex. Thom & Co., Ltd., 1935); Joseph Foster, *Alumni Oxonienses: The Members of the University of Oxford, 1715-1886: Their Parentage, Birthplace, and Year of Birth, with a Record of Their Degrees* (Oxford and London: Parker and Co., 1887-1888); John Venn, *Alumni Cantabrigienses: A Biographical List of All Known Students, Graduates and Holders of Office at the University of Cambridge* (Cambridge: University Press, 1922-54); *J.C. Poggendorff's Biographisch-Literarisches Handwörterbuch zur Geschichte der Exacten Wissenschaften* (Leipzig: Johann Ambrosius Barth, 1863-1926); Sir Leslie Stephen and Sir Sidney Lee, ed., *Dictionary of National Biography*, (London: Oxford University Press, 1885-1985); *Modern English Biography*, ed. Frederic Boase, (London: Frank Cass & Co. Ltd, 1965); *Royal Society of Edinburgh: Index of Fellows Elected 1783 to 1883* (Edinburgh: Scotland's Cultural Heritage, 1984); and membership lists of the London Mathematical Society for 1865, 1887 and 1903, and for the Edinburgh Mathematical Society for 1904.

[5]Lawrence Stone, "Prosopography," *Daedalus* 100 (1971): 46-79 on p. 69.

in discussing her use of prosopography to study pre-World War II Nobel prize winners, Elisabeth Crawford asserted that "prosopography is... best used in conjunction with other methods. The most common one is the historical narrative that places the population studied in its context — institutional, intellectual, or political — and analyzes it in relation to this context."[6] This chapter will contextualize the domestic mathematical contributors in both their educational and economic settings. Chapters 6 and 7 will carry that contextualization further — into the international and intellectual, mathematical settings, respectively.

Entering the Discipline: Mathematical Training of Domestic Contributors

This prosopography presents the educational backgrounds of 627 (or 72%) of the domestic contributors found in the biographical sources. Of those contributors with recorded educational training, over 85% received a Bachelor or Master of Arts degree from a British institution (see Table 5A). While this might seem to imply a high degree of uniformity in the training of these mathematicians, the requirements, or lack thereof, for these degrees differed markedly throughout Britain.

While candidates for the BA at Cambridge and Oxford had to pass examinations for their degree, the requirements for the MA at these universities were at most formalities for Anglicans;[7] until 1856 at Cambridge and 1871 at Oxford, religious

[6]Elisabeth Crawford, *Nationalism and Internationalism in Science, 1880-1939* (Cambridge: University Press, 1992), p. 26.

[7]While a degree examination for the MA existed in theory at Oxford from 1800 to 1807, it seems to have never taken place. A minimum residence period of three weeks was required for the MA until 1859. At Cambridge, the residency requirement for the MA was dropped in 1608, and the remaining requirements were only formalities. M.C. Curthoys, "The Examination System," in *The History of the University of Oxford: Nineteenth-Century Oxford, Part I*, ed. M.G. Brock and M.C. Curthoys, (Oxford: Clarendon Press, 1997), pp. 340-374 on p. 343; W.H. Walsh, "The Zenith of Greats," in

tests made the degree unattainable for those not allied with the Church of England.[8] While the MA was also a formality at Trinity College, Dublin, the BA required students to earn their degrees through a cumulative series of tests instead of a final degree examination as at Oxbridge.[9] The MA had yet another meaning to students at Scottish universities. At Glasgow, Edinburgh, and St. Andrew's, the MA was conferred only after a prescribed course of study and examinations; in fact, by 1861, all three universities abolished the BA, leaving the MA as the primary Arts degree.[10] In effect, Scotland's "strong Masters degree if anything swallowed up the Bachelors degree, rather than the other way about as in England."[11]

The University of London, founded in 1836 for the purpose of examining and conferring degrees on students from University College, London and King's College, held demanding examinations for both the BA and the MA.[12] While criticized for the severity of these examinations, the University's Senate believed "[i]t would be very unwise...for the new national university to be an easy touch for degrees in

The History of the University of Oxford: Nineteenth-Century Oxford, Part II, ed. M.G. Brock and M.C. Curthoys, (Oxford: Clarendon Press, 2000), pp. 311-326 on p. 312; and W.W. Rouse Ball, *A History of the Study of Mathematics at Cambridge*, (Cambridge: University Press, 1889), p. 157.

[8]Christopher Harvie, "Reform and Expansion, 1854-1871," in *History of Oxford, Part I*, pp. 698-730 on p. 728; and Christopher N.L. Brooke, ed., *A History of the University of Cambridge*, vol. IV, *1870-1990* (Cambridge: University Press, 1993), p. 99.

[9]This format allowed a non-resident to earn a degree from Trinity. Non-resident students living in England were said to earn a "steamboat degree." R.B. McDowell and D.A. Webb, *Trinity College Dublin 1592-1952: An Academic History* (Cambridge: University Press, 1982), pp. 117, 127. Sylvester, for example, earned such steamboat degrees from Trinity in 1841 after ranking as a Second Wrangler at Cambridge in 1837; because he was a Jew, he was restricted from taking the Cambridge degrees. For more on his situation, see below.

[10]J.D. Mackie, *The University of Glasgow, 1451-1951* (Glasgow: Jackson, Son, & Co., 1954), pp. 251-252, 273; and D.B. Horn, *A Short History of the University of Edinburgh* (Edinburgh: University Press, 1967), pp. 161, 175.

[11]Renate Simpson, *How the PhD Came to Britain: A Century of Struggle for Postgraduate Education* (Surrey, UK: The Society for Research into Higher Education, 1983), p. 68.

[12]Negley Harte, *The University of London 1836-1986* (London and Atlantic Highlands, NJ: The Athlone Press, 1986), p. 93.

an increasingly qualifications-conscious society needing a mould in which to set its educational system."[13]

The effects of these differing degree requirements are reflected in Table 5A.[14]

Table 5A: BAs and MAs Received by Domestic Mathematical Contributors

	Cam.	TCD	Oxford	Glasgow	Edin.	U. London	Other*	Total†
BA	367	58	45	2	2	12	10	496
MA	334	48	44	23	20	8	24	501

* These institutions are Aberdeen University; University College, Bristol; Royal Military Academy, Woolwich; St. Andrews; Melbourne University; Queen's University, Ireland; Royal University, Ireland; Queen's College, Belfast. The institutional origin of two BAs and nine MAs are unknown.

† 536 out of the 874 domestic contributors (61%) for this study received one or more of the BAs and/or MAs listed above. The other 91 contributors for which we have educational information are discussed in the tables and text below.

The Scottish universities' abolition of the BA helps explain the higher overall number of MAs earned by the domestic contributors. At Cambridge, Oxford, and Dublin, the small differences between the number of BAs and MAs reflect the virtual inevitability of receiving the latter degree after the former. However, not all of the domestic contributors educated at these institutions proceeded to the higher degree. Early deaths ended the academic careers of at least two of these contributors;[15] religious

[13] *Ibid*, p. 95.

[14] The unavailability of alumni lists from universities other than Cambridge, Oxford, Trinity College, Dublin, Glasgow, and Edinburgh may cause Table 5A to underestimate the number of degrees from those universities. However, since the general biographical sources used list the educational backgrounds from all universities and as educational information was found for 72% of the subjects for this prosopography, Table 5A gives a fairly accurate picture of the educational attainments of this group.

[15] While George Green became a Fellow at Gonville and Caius College, Cambridge in 1839, he resided only two terms and died in 1841 without the MA. Henry John Purkiss drowned in the River Cam in 1865, one year after receiving his BA. Doris Mary Cannell, *George Green: Mathematician and Physicist 1793-1841* (London: Athlone Press, 1993), p. 115; and *Alumni Cantabrigienses*, s.v. "Purkiss, Henry John."

issues provide another explanation for these exceptional graduates. For example, Augustus De Morgan, a self-described "christian unattached," spurned the MA and a possibility for a fellowship because he was opposed to Cambridge's religious tests.[16]

Cambridge clearly represented the focal point for the mathematical training of domestic contributors, educating almost 70% of those earning an Arts degrees. The importance of a Cambridge education to these mathematicians is also evidenced by the fact that at least 24 earned degrees at other British universities before finishing their undergraduate studies at Cambridge.[17]

Cambridge owed much of its preeminence in mathematics to its mathematical Tripos examination.[18] This examination, for over half the nineteenth century, was a mandatory hurdle for the BA degree at Cambridge (even for those students interested in non-mathematical areas). A high ranking among the Wranglers, the highest honor bracket for the examination, provided access to promising positions in the university, church, and government. Thus, it is not surprising that attaining high marks on this examination formed one of the first mathematical goals for many of the members of the British mathematical publication community: over one-third of the domestic contributors identified here scored as Wranglers on the Tripos.[19] Of these Wranglers,

---

[16] *Alumni Cantabrigienses*, s.v. "De Morgan, Augustus."

[17] If we also consider students studying at, but not actually obtaining degrees from, these institutions, the number of contributors receiving university training before entering Cambridge would certainly be much higher. However, since several of the university sources for this study recorded information only for graduates, in most cases, only the degrees obtained have been recorded.

[18] Recall chapter 4 for information about the Tripos examination.

[19] 313 subjects in this study (36%) scored as Wranglers on the Tripos: 53 as Senior Wranglers, 42 as Second Wranglers, 133 as third through Tenth Wranglers, and 85 as 11th or greater Wranglers. Among these, Sylvester, who was ranked as the Second Wrangler for 1837, was forced to wait 35 years for his two Arts degrees. As a Jew, Sylvester was allowed to matriculate and take examinations at Cambridge, but religious tests barred him from taking a degree or a fellowship, which his high

96 won one of the other major mathematical distinctions at Cambridge, the Smith's prizes.[20] The high number of nineteenth-century Wranglers and Smith's Prizemen among the domestic mathematical contributors suggests that the Cambridge examination system predicted and encouraged those who had an interest in mathematical research. While these examinations, as well as other facets of the Cambridge educational system, provided a substantial number of students with the training requisite for entering the mathematical publication community, the preparation necessary for a high ranking on these examinations also circumscribed the initial mathematical exposure of Wranglers and Prizemen. The course of mathematical study at Cambridge was thus, on the one hand, compelling and rewarding but, on the other hand, competitive and bounded.

The mathematical atmosphere at Cambridge fostered by its examinations drew pointed criticism from Augustus De Morgan. Comparing the educational frameworks of the two ancient English universities, he stated that "[t]he Oxford system has a tendency to develop the useful differences between the varied types of human character. The Cambridge system is an unconscious effort to destroy them."[21] Despite De Morgan's glowing assessment of Oxford, the domestic contributors in this prosopography were over ten times more likely to pursue their mathematical training in Cambridge.

place on the Tripos would have virtually assured. Phillipa Garrett Fawcett, one of the five women in this sample, was ranked above the Senior Wrangler for 1890, but could not receive the distinction or a degree because of her sex. At both Cambridge and Oxford, women were barred from taking degrees throughout the nineteenth century.

[20]For a discussion of these prizes, recall chapter 4.

[21]Augustus De Morgan, *Memoir of Augustus De Morgan* (London: Longmans, Green & Co., 1882), p. 226, in Adrian Rice, "Mathematics in the Metropolis: A Survey of Victorian London," *Historia Mathematica* 23 (1996): 376-417 on p. 381.

In fact, Oxford mathematics has been characterized as "always in the shadow of classics."[22] Before 1864, a final examination in classics, instead of mathematics as at Cambridge, was required for all Oxford BA candidates.[23] While an Oxford student could obtain honors in mathematics through examinations, the numbers who chose to do so paled in comparison with those of Cambridge. For the last three decades of the nineteenth century, although over 100 Cambridge students per year on average took mathematical honors in the Tripos, only around 20 per year took these honors at Oxford.[24] Moreover, throughout the nineteenth century, the numbers of matriculants at both universities were roughly equal;[25] thus, mathematical honors students at Oxford made up a much smaller percentage of the university population than at Cambridge.

Student matriculations at Trinity College, Dublin also closely matched that of Cambridge for the early nineteenth century. However, after 1824, matriculations at Dublin began to decline until they dipped to around 200 by 1900; at Cambridge, they experienced a 30-year plateau and subsequent rapid growth to over 900 by the end of the century.[26] Trinity College, Dublin's position in this study as the second (even if a distant second) most popular institution at which to pursue an undergraduate degree reflects a high degree of mathematical influence on its students.[27]

---

[22]Keith Hannabuss, "Mathematics," in *History of Oxford, Part II*, pp. 443-455 on p. 443.

[23]*Ibid.*, p. 444.

[24]Robert Fox, "The University Museum and Oxford Science, 1850-1880," in *History of Oxford, Part I*, pp. 641-691 on p. 672.

[25]Lawrence Stone, "The Size and Composition of the Oxford Student Body 1580-1910," in *The University in Society*, 2 vols., ed. Lawrence Stone (Princeton: University Press, 1974), 1: 3-110 on p. 6.

[26]*Ibid.*, p. 6; and McDowell and Webb, p. 500.

[27]For more on Dublin's nineteenth-century mathematical program, recall chapter 4.

While Edinburgh ranks fifth in awarding Arts degrees, it ranks a close second in awarding the BSc (see Table 5B). Established in 1864 along with the DSc, this degree could be taken with a focus on the mathematical, physical, or natural sciences.[28] In Glasgow, the BSc was created six years later and required students to add four subjects to their standard Arts curriculum from the biology, geology, engineering, or law departments.[29]

Table 5B: Other Degrees Obtained by Domestic Contributors

	Cam.	TCD	Oxford	Glasg.	Edin.	U. Lond.	Other	Total
BSc				3	12	14	1[*]	30
ScD or DSc	27	2	2	5	6	18	16[†]	76
BD	8	11	3	1	2		1	26
DD	8	13	3		3		1[‡]	28
MB	5	2			4		1[§]	12
MD	4	3			3		3[§ ♯]	13
LLD	3	10		2		1	7[‡ §]	23

* Birmingham.

† One each at Aberdeen, Adelaide, Belfast, Manchester, Royal University, Ireland, and Kapstadt. The origins of ten of these degrees are unknown.

‡ St. Andrews.

§ Unknown.

♯ Aberdeen.

Instead of representing a broadening of the original required classes for an Arts student, the Bachelor of Science at the University of London, the first ranked institution in awarding this degree, aimed to help students streamline their science studies. The idea of introducing a Bachelor of Science degree was considered at the University

[28] Horn, p. 179.

[29] Mackie, p. 273.

of London during its 1858 deliberations on reforming its charter. In a memorial signed by 20 scientists and addressed to the University, the author, supposedly the biologist Thomas H. Huxley, argued that

> [s]cience... has gradually grown up, and being unrecognised as a whole, has become dismembered; some fragments consisting of Mathematics and such branches of Physics as are capable of Mathematical treatment, attaching themselves to Arts; others, such as Comparative Anatomy, Physiology, and Botany, clinging to Medicine, amidst whose professors they took their rise... The Academic bodies... continue to ignore Science as a separate Profession; and even the University of London, though especially instituted to meet the wants of modern times, can confer no Degree upon the first Chemist and Physicist of his age, unless he possess at the same time more than average acquaintance with classical literature... We conceive such a state of things as this not only anomalous in itself, but in the highest degree injurious to the progress of Science; for those who have the direction of youth, finding Science unrecognised as a profession discourage it as a pursuit ... The remedy for these evils appears to us to be, that the Academic bodies in this country should... recognise 'Science' as a Discipline and as a Calling, and should place it on the same footing with regard to Arts, as Medicine and Law.[30]

In response to these sentiments, the University of London founded a new Faculty of Science in addition to the BSc and DSc degrees. The examinations required for the BSc covered a wide variety of scientific areas. Additional specialized examinations were established for taking honors in specific areas. Alexander Crum Brown, a domestic mathematical contributor to the *Transactions of the Royal Society of Edinburgh* and the *Proceedings of the Edinburgh Mathematical Society*, took the University of London's first BSc in 1860 and two years later earned the institution's first DSc.[31] While Crum Brown obtained his DSc through examinations, by 1886, a thesis of original work became the degree requirement for the University of London.[32]

[30] *Minutes of the Senate*, 12 May 1858, quoted in Harte, pp. 109-110.
[31] Harte, p. 111.
[32] *Ibid.*, p. 135.

Following the trend set by the University of London and Edinburgh, Cambridge began awarding the ScD in 1883.[33] This innovation proved to be popular: in its first ten years of existence, the Cambridge Doctorate of Science was awarded to 24 scholars,[34] 13 of whom contributed to the mathematical publication community. The requirements for these new degrees underwent a period of adjustment, and the first recipients of these credentials were not always traditionally aged students: "[n]aturally the older men, both those still in Cambridge and those who had taken posts elsewhere, saw themselves as the most distinguished representatives of their chosen fields, and many of them applied for the new degrees and could not but be appraised by their juniors, who, by and large, took a lenient view of outmoded learning."[35] Over half of the 13 science doctors referred to above had become MAs at least 20, and as much as 41, years earlier. The degree was to be awarded for published works, and the three ScDs in this study who earned the degree in its second decade at Cambridge received their doctorate within ten years of the MA; however, for the remaining nine receiving the degree during the twentieth century, as much as 28 years separated the transition from master to doctor.[36]

By 1895, all four of the Scottish universities (Glasgow, Edinburgh, St. Andrews, and Aberdeen) had established five-year research programs leading to the DSc, DLitt, and the DPhil.[37] In the same year, Oxford adopted the BSc; however, the DSc

[33]Simpson, p. 63.
[34]*Ibid.*
[35]Elisabeth Leedham-Green, *A Concise History of the University of Cambridge* (Cambridge: University Press, 1996), p. 169.
[36]The years of two Cambridge ScDs were not available.
[37]Simpson p. 67.

arrived there only in 1900.[38] Before the institution of the new degree path, which rewarded young scholars' research, seniority within the University had been the means to institutional rewards. As Janet Howarth pointed out, imposing a new system of research recognition on top of an old system of seniority caused "much irritation... [in particular] in establishing the seniority of holders of the DLitt and DSc degrees in relation to heads of houses without doctorates, and on examining boards.[39]

The process of providing science-focused and post-graduate degree programs for British students was slow and tentative during the last third of the nineteenth century. Historian of British higher education, Renate Simpson, asserted that even at the beginning of the twentieth century, "while certain individual teachers gave a great deal of their time and experience to a few outstanding students, there was nothing that could as yet be even remotely described as *systematic instruction* for graduate students."[40] The doctorate, firmly established in the German and American educational systems during the nineteenth century, did not reach Britain until 1917,[41] and at least 13 of the 14 PhD holders in this prosopography received the degree in Germany.[42] However, the nineteenth-century curricular introduction of the BSc and DSc into Britain represented a recognition of science as a distinct discipline and of research as a proper activity for students.[43]

[38]A.J. Engle, *From Clergyman to Don: The Rise of the Academic Profession in Nineteenth-Century Oxford* (Oxford: Clarendon Press, 1983), p. 265.

[39]Janet Howarth, "The Self-Governing University, 1882-1914," in *The History of Oxford, Part II,* pp. 599-643 on p. 619.

[40]Simpson, p. 67. Emphasis hers.

[41]*Ibid.*, p. 135.

[42]The origin of one PhD has not been determined.

[43]Two people in the mathematical publication community, Robert Samuel Heath and Stanley Dunkerley, earned MSc's from the provincial universities of Birmingham and Victoria.

Although the majority of domestic contributors in this study took degrees in the Arts or the emerging departments of science, some took degrees in the areas of divinity, medicine, and law (see Table 5B). Like the MA, these degrees had different and fluid meanings at different British universities. At Oxford and Cambridge for much of the nineteenth century, these professional degrees were awarded basically for paying the proper fees.[44] Among these, the Bachelor of Divinity (BD) was required for some fellows; receipt of this degree, while not academically difficult to attain, "was a demoralizing and expensive business, since... the necessary exercise for that degree had been reduced to no more than a ritual, accompanied by payment of an onerous fee."[45] At nineteenth-century Edinburgh, the Doctorates of Laws (LLD) and Divinity (DD) were considered honorary, but the bachelors' degrees in these areas (LLB and BD) as well as the medical degrees at both levels (MB and MD) were awarded on the merits of examinations or theses.[46]

Regardless of their requirements, the divinity degrees, among the domestic members of the mathematical publication community, were strongly linked to religious careers. Of the 37 men holding one or both of these degrees, all but ten held clerical posts or had taken holy orders. While a life devoted to the Church would today seem to preclude one devoted to mathematics, in nineteenth-century Britain, these two devotions could — and did — coexist in one person. George Salmon was a prime example of someone moving equally well in the mathematical and theological domains

[44]Simpson, p. 12

[45]*Ibid.*, p. 9.

[46]Horn, pp. 163, 178.

of a British university. After graduating with mathematical honors from Trinity College, Dublin in 1838, Salmon proceeded to ordination as deacon in 1844, and as priest in 1845. From the 1840s to the 1860s, he lectured in both divinity and mathematics at the Dublin university. Receiving the BD and DD in 1859, he proceeded seven years later to the Regius Professorship of Divinity, a position he held until being appointed Provost of the University in 1888. From the 1840s to the 1870s, he published both mathematical and theological tracts, and some of his works from both fields went through multiple editions.[47] However, as an 1870 letter from Salmon to his colleague in invariant theoretical researches, Sylvester, shows, Salmon's work in divinity slowly edged out his mathematical research. In his letter, Salmon complained that in mathematics "alas I am become very rusty; learning nothing new & forgetting half the old."[48]

Another field that provided a livelihood, but not explicit research time for mathematics was medicine. Physicians also made mathematical contributions and account for over one third of the 20 holders of an MB or MD.[49] Doctors in Law, however, were much more likely to reflect recognition of an illustrious career than a future legal career. Of the 42 subjects in this study with an LLD or a DCL (Doctorate of Civil Law), less than a quarter had ever held a job in the legal field. Furthermore,

[47]For example, *The Infallibility of the Church* and *Lessons Introductory to the Modern Higher Algebra*. *Dictionary of National Biography,* s.v."Salmon, George."

[48]George Salmon to J.J. Sylvester, 18 April 1877, in Karen Hunger Parshall, *James Joseph Sylvester: Life and Work in Letters* (Oxford: Clarendon Press, 1998), p. 175. For more on Salmon's research before and after taking the Professorship in Divinity, see the case study on analytic geometry in chapter 7.

[49]Of the other 13 degree holders, eight held science positions at universities, one taught secondary school, one was a member of parliament, one was a businessman, and the subsequent careers of two is unknown.

two of these, Sylvester and Cayley, received LLDs *after* leaving the law to become mathematics professors. At least one-half of these law doctorates were received prior to the 1880s, before DScs were widely available in Britain. In the absence of science doctorates, higher degrees in law represented a way to recognize the scholarship of British mathematicians.

In addition to these law doctorates, 317 degrees specifically deemed as honorary were awarded to 121 domestic contributors.[50] While the metropolitan, Scottish, and ancient English universities awarded the majority of these degrees, a variety of other institutions also recognized British mathematicians in this manner. American and European universities awarded 50 of these honorary degrees, and British provincial and colonial universities awarded 63 such degrees to members of this group. For example, the Cambridge Senior Wrangler and First Smith's Prizeman for 1881 and the Sadleirian Professor of Pure Mathematics at Cambridge from 1895 to 1910, Andrew Forsyth, received degrees from Victoria University, Manchester, Liverpool, Wales, Aberdeen, Calcutta, and Christiania. Like society memberships or medals,[51] honorary degrees marked the accomplishments of domestic mathematicians, while they improved the reputation of the awarding body.

British university degrees could be the result of competitive examinations or, as was sometimes the case near the end of the nineteenth century, original research.

[50]These domestic contributors received 123 honorary LLDs, 33 honorary DCLs, 96 honorary DScs or ScDs, three honorary LLBs, three honorary MDs, five honorary DDs, eight honorary PhDs, and 46 other honorary degrees.

[51]On the use of medals or memberships to help British mathematics enter the international arena, see chapter 6.

Alternatively, these degrees could be awarded to recognize eminence or simply the fulfillment of some formal (often monetary) requirements. The variety of functions and requirements of these degrees and the variety of disciplines from which the domestic contributors took degrees implies that the educational path for a mathematician in nineteenth-century Britain was not yet strictly defined. The employment possibilities of these domestic contributors after taking their degrees were also broadly defined and could differ markedly from the career paths of mathematicians today.

Earning a Living: The Careers of Domestic Contributors

In May, 1851, the young biologist Thomas Huxley wrote that "I could get anything I write into any of the journals or any of the Transactions, but I know no means of thereby earning five shillings. A man who chooses a life of science chooses not a life of poverty, but, so far as I can see, a life of *nothing*, and the art of living upon nothing at all has yet to be discovered."[52] While Huxley was not a mathematician, his lament reflected the plight of many of the subjects of this prosopography. Their post-graduate careers were diverse and not always related to mathematics. Even when they did find employment in a mathematically related area, in most cases, their job expectations could be at best only tangentially related to mathematical research.

Table 5C follows the careers of these mathematicians throughout the nineteenth century. However, in order to gain a sense of the occupations of the domestic publication community, the table is limited to tracing the activities of these mathematicians

[52]Thomas Henry Huxley, quoted in Leonard Huxley, *Life and Letters of Thomas Henry Huxley*, vol. 1, (London: Macmillan and Co., 1913), p. 100.

Table 5C: Professions of Domestic Contributors

	1800s	1810s	1820s	1830s	1840s	1850s	1860s	1870s	1880s	1890s
Subjects of Prosop.*	24	25	31	75	77	119	147	173	246	258
Student¶	3	5	7	30	28	30	45	48	60	70
College or Univ. Position/ not Professor♯	3	2	8	16	26	33	42	57	85	83
Private Coach				1	1		2	1	1	2
Professor	7	8	4	20	25	26	31	35	50	57
Observ. Position	3	2	3	4	6	6	6	2	3	8
Teacher	1	3	4	6	2	3	14	14	22	22
Secdy. Educ. Admin.						1	1	3	3	2
Church Position †	2	4	4	7	9	11	13	13	14	11
Law/Actuary		1	2	4	9	13	7	4	3	3
Judge						1	2	2	1	2
Member of Parliament			2	2		1			1	1
Physician		2	1	1	1	1	1		1	
Retired			2	3	2	2	2		2	2
Other‡	2	3	3	6	7	17	20	22	20	12
Unknown§	5	5	8	15	13	27	29	40	53	72

* These represent the domestic contributors writing over a given decade. Those writing over more than one decade are counted in each. Information on the professions of 687 (79%) of the domestic contributors has been found, and only these members are presented in this table. Since a contributor may hold more than one occupation in a given decade, the columns in Table 5C may add to more than the number of subjects in the prosopography.

¶ Students studying or receiving a BA, MA, BSc, MSc, MB, or MD One student listed received the equivalent to BA, and one studied in England temporarily.

♯ Fellow, Tutor, Lecturer, Examiner, Assistant to Professor, Demonstrator, Bursar, Dean, Master, Esquire Bedell, President, Principal, Provost, or Registrar.

† Vicar, Rector, Dean, Canon, Bishop, Archdeacon, chaplain, minister, or preacher.

‡ Master of the Mint, Chief Baron of Exchequer, private man, engineer, printer, editor, writer, architect, banker, pawbroker, librarian, museum curator, businessman, civil servant, electrician, military officer, stockbroker, recluse, exile, clerk, deceased (contribution printed posthumously).

§ While professional information is known for these contributors, it is not known (or was not specified) for the period in which they were writing.

only while they were actively contributing to the journals in this study.[53] Information has been found on the professions of 687 (79%) of the domestic contributors; however, since the tenures for these positions have not always been specified or have fallen outside of the publication period of contributors, Table 5C does not record all of the available occupational information.[54]

For any decade in the nineteenth century, the percentage of students writing in the journals of this study ranged from 13% to 40% of the contributors for whom occupational information is available. Thus, a substantial proportion of the subjects in this prosopography began — and in many cases ended — their mathematical contributions to journals while still in school. For example, 12th Wrangler in 1855 and soon to be Cambridge Master of Arts, John Prescott, made his mathematical publication début in the second volume of the *Quarterly Journal for Pure and Applied Mathematics* with that volume's first article, "On the Wave Surface."[55] Soon after this article's publication, Prescott began a career with the Church in which he eventually assumed the archdeaconry of Carlisle. Prescott continued writing, but changed his focus from mathematics to theology. His début in the mathematical publication community was thus also his mathematical swan song: this article is his only entry in the *Royal Society Catalogue of Scientific Papers*, and his Cambridge biographical

[53]For example, a Cambridge student who made a contribution in the 1820s, and then became a physician and never made another mathematical contribution will be counted in Table 5C only as a student for the 1820s. A contributor whose publication tenure spanned more than one decade is counted in each decade of his publishing career (defined here as the period from first to last contribution) and is listed under the occupation(s) held at that time.

[54]If a contributor's tenure in a position fell within two years before the first publication, this position is counted in Table 5C.

[55]John Eustace Prescott, "On the Wave Surface," *Quarterly Journal of Pure and Applied Mathematics* 2 (1857): 1-8.

entry only records him as authoring such works as *Everyday Scripture Difficulties* and *Christian Hymns and Hymn Writers*.[56] Like Prescott, Cambridge and Oxford BAs contributing mathematical articles while waiting to receive their MAs are classified as students in Table 5C. Unlike the Scottish MA candidates, these BAs had no academic hurdles to jump to receive their degrees; however, they may still be regarded as fresh graduates preparing for future careers.

Many of these graduates — over one quarter for each decade from the 1830s to the 1890s of the prosopography subjects for which we have occupational information — chose to stay for some time in the academic environment and to work in a variety of positions offered by colleges or universities. The first such position to which a British graduate could aspire was a fellowship. During the early nineteenth century, this position was seen by many as a stepping-stone to careers in the Church or other professions; excepting the most senior of this group who ascended to administrative positions in their colleges, fellows did not see their post as a lifelong career.[57] Although the specific regulations varied from college to college, in general, these fellowships could be held for life, given that a fellow remained celibate and took holy orders within a given number of years.[58] Thus, while fellows enjoyed a high degree of job security, the restrictions attached to this long tenure encouraged many to resign, or

[56] *Alumni Cantabrigienses*, s.v. "Prescott, John Eustace."

[57] Arthur Engle, "Emerging Concepts of the Academic Profession at Oxford 1800-1854," in *The University in Society*, 1: 305-352 on p. 308; Sheldon Rothblatt, *The Revolution of the Dons: Cambridge and Society in Victorian England* (New York: Basic Books, Inc., 1968) p. 198; and McDowell and Webb, pp. 106-109.

[58] Arthur Engle, "Emerging Concepts," pp. 305-352, on p. 306-307; and McDowell and Webb, p. 106. These celibacy requirements at Cambridge and Oxford were lifted by the 1880s. Leedham-Green, p. 168; and Engle, "Emerging Concepts," on p. 349. The career implications of the lifting of this requirement is discussed below.

in the case of the Dublin fellows, to engage in "semi-clandestine marriages."[59]

At Cambridge during the first half of the nineteenth century, a high ranking Wrangler on the mathematical Tripos could be virtually guaranteed a fellowship.[60] Mathematical ability also represented the key to gaining a Dublin fellowship at this time, since the examination for the position was dominated by mathematics.[61] At Oxford, fellowships were "traditionally hedged about with a mass of conditions."[62] Restrictions on the of place of birth, schools, and families of fellowship candidates resulted in only around 22 of the over 400 fellowships being open to all graduates.[63] While reforms in 1854 eliminated most of these restrictions,[64] throughout the nineteenth century, most of those elected still had a classical, rather than mathematical, background.[65] It is not surprising, then, that the domestic members of the mathematical publication community were most likely to be elected to a Cambridge fellowship, with Dublin a respectable second considering its limited number of fellowship positions, and Oxford third.[66]

The duties of these fellows varied widely between Oxbridge and Dublin. Financial

[59]McDowell and Webb, pp. 106-107. At least 16 of the 25 fellows of 1811 were married; the Dublin administrators closed their eyes to this. Regulations on celibacy were tightened in 1812, but were completely removed by 1840. *Ibid.*

[60]Rothblatt, p. 181. Trinity College, Cambridge, was the exception, requiring its fellowship candidates to take an examination focused on both classics and mathematics. Denys A. Winstanley, *Early Victorian Cambridge* (Cambridge: University Press, 1940; reprint ed., New York: Arno Press, 1977), pp. 424-425.

[61]McDowell and Webb, p. 231.

[62]M.C. Curthoys, "The 'Unreformed' Colleges," *History of Oxford, Part I*, pp. 146-173, on p. 168.

[63]*Ibid.*

[64]Engle, "Emerging Concepts," pp. 347-350.

[65]Howarth, p. 609

[66]Among the subjects of this prosopography, at least 200 were elected as Cambridge fellows, 24 at Trinity College, Dublin, 23 at Oxford, five at the Royal University of Ireland, four at the University of London, two at King's College, London, one at University College, London, one at Durham, and one at Allahabad University. Honorary fellowships were not counted in this study.

stringency in early nineteenth-century Dublin limited the number of fellows and therefore presented them with a formidable teaching load.[67] In 1830, the 18 junior fellows at Dublin provided most of the educational instruction of the College, oversaw the quarterly examinations for all undergraduates, and held various administrative positions.[68] A fellow providing tuition had, on average, over 100 students with which to contend.[69] These duties allowed little time for research. Thomas Robinson, who contributed to the mathematical journals in this study only after his tenure as a Dublin Fellow (1814-1821), wrote in 1820 that, "[u]nder the system pursued at present in Trinity College, its fellows can scarcely be expected to devote themselves to any work of research or even of compilation; constantly employed in the duties of tuition, which harass the mind more than the most abstract studies, they can have but little inclination, at the close of the day, to commence a new career of labour. How different is this from the state of the English Universities."[70]

At Oxford, both the number of fellows and the percentage employed in teaching were drastically different from those of Trinity College, Dublin. The Oxford fellows numbered in the hundreds, and the percentage of those engaged as educators at their university hovered around 10% for the first half of the nineteenth century.[71] Those fellows without duties, called "idle fellows" by their critics, could use their positions

[67]McDowell and Webb, p. 110.

[68]In addition to these junior fellows, senior fellows, along with the provost, handled the government of the university. McDowell and Webb, p. 97.

[69]*Ibid.*, p. 105.

[70]Thomas Romney Robinson, *A System of Mechanics*, (Dublin, 1820), pp. vi-vii, quoted in McDowell and Webb, p. 105.

[71]J.P.D. Dunbabin, "Finance and Property," in *History of Oxford, Part I*, pp. 375-437 on p. 408.

as a form of income while beginning their careers and often lived outside of Oxford.[72]

A similarly "idle" class of fellows apparently existed at Cambridge. According to the estimate of two fellows in 1840, "if the whole society [of Trinity College, Cambridge] were now in residence, three-fourths of the body would be unemployed, or busy only in private and for themselves."[73] For the fellow who did work as college tutor, Leslie Stephen indicated that many obstacles could prevent him from being a devoted teacher:

> [a tutor] may go beyond the ordinary routine of lectures and endeavour to teach his pupils something... The objections to this course are, however, obvious. In the first place, it takes much time and trouble, for which he receives no extra pay, and even in a model University, we can't rely exclusively upon unselfish motives of action. Again, a college tutor, whose mind is incessantly distracted by the cares of office, by corresponding with parents, maintaining discipline, and a hundred vexatious details, cannot, as a rule, successfully compete with the private coach. And, finally, if the tutor considers himself, as he of course, should, as the caterpillar which is to be developed into the butterfly dignity of a bishop, a head of a house, or, at lowest, a divinity professor, the drudgery of teaching prevents him from studying the full graces of his character.[74]

While Stephen's colorful account may lean towards exaggeration, for most of the nineteenth century, Cambridge students certainly did not find the education provided by a college tutor as adequate for the rigors of their examinations. To supplement their instruction, these students employed private coaches.

In response to the establishment of the Tripos examination, Cambridge students during the late eighteenth century had begun to seek out and pay for extra help

[72]Engle, "Emerging Concepts," p. 309; and M.C. Curthoys, "The Colleges in the New Era," in *History of Oxford, Part II*, pp. 115-157 on p. 132.

[73]*An Earnest Appeal to the Master and Seniors of Trinity College, Cambridge, on the Revision of the Statutes: By Two of the Fellows* (1840), quoted in Winstanley, p. 404.

[74][Leslie Stephen], *Sketches of Cambridge by a Don* (London: Oxford University Press, 1932), p. 81.

with their studies. Gradually, these private studies began to eclipse those received in college, and by the mid-nineteenth century, private coaching represented a vital component of the Cambridge education: "[i]t was certainly apparent that coaches were not simply providing supplementary or remedial instruction. They were the most important teachers in the university: and all undergraduates were forced to use them."[75] To the many fellows who had no formal teaching duties, this opportunity for activity and financial reward proved irresistible.[76] Even for a fellow who tutored for his college, the prospect of extra earnings could sway him to coach. For Cambridge graduates hoping eventually to receive fellowships, for those barred from fellowships because of marriage or religious issues, and for those whose poverty had driven up debts which needed to be repaid, coaching provided an employment solution.[77] To be profitable, however, private coaching exacted a huge time commitment: "[a] well-paid coach had to be competitive, sure of his technique, well-organized and willing to work at least six hard tutorial hours every day, as well as grade written exercises and problem sets."[78] The work was far from intellectually stimulating, especially for those giving remedial tutoring to ill prepared students, and while the income earned could be great, it was uncertain.

Rothblatt asserted that "[v]irtually every graduate living in Cambridge, whether a fellow or not, tried coaching because the remuneration was exceptionally good... an ordinary private coach could make £252 per academic year, or about £50 less than the

[75]Rothblatt, p. 198.
[76]*Ibid.*, p. 201.
[77]*Ibid.*, p. 207.
[78]*Ibid.*, p. 199.

customary value of a fellowship in the mid-nineteenth century."[79] Moreover, Rouse Ball stated that these coaches had no lack of clientele: "[d]uring the first three-quarters of the present [19th] century... nearly every mathematical student read with a private tutor."[80] These statements, together with the low numbers of private coaches in Table 5C, could imply these coaches had no time to contribute mathematical articles to journals. However, the biographies of 25 domestic contributors indicate some private coaching, but many of these do not provide the time period during which this tutoring occurred. Moreover, the temporary nature of coaching could result in it not being recorded in the biographies of all but the most devoted coaches.

One such coach, Edward Routh, chose tutoring as a lifelong career and also contributed extensively to the journals. After graduating in 1854 as Senior Wrangler and First Smith's Prizeman under the tuition of Cambridge's second biggest Wrangler maker, William Hopkins, Routh began coaching. He continued to offer private tuition after being predictably elected a Fellow of Peterhouse College and beginning a 49-year-long tenure as a college lecturer in mathematics.[81] His success in guiding students towards Cambridge mathematical honors was unparalleled: of his over 600 students, 27 took Senior Wranglerships and 41 became Smith's Prizemen.[82] The keys to his success involved teaching the subjects of the Tripos in the right proportions and relentlessly testing and ranking his students. This methodology reflected the Tri-

[79] *Ibid.*, p. 200.

[80] W.W. Rouse Ball, *A History of the Study of Mathematics at Cambridge* (Cambridge: University Press, 1889), pp. 162-163.

[81] Thus, in Table 5C, Routh is listed under the categories of "Private Coach" and "College or University Position/ non Professor."

[82] *Dictionary of National Biography,* s.v. "Routh, Edward John."

pos's ability simultaneously to encourage and circumscribe mathematical learning. With successful techniques that kept his coaching business flourishing, Routh left his fellowship in 1864 to marry the eldest daughter of the Astronomer Royal, Sir George Airy.[83] While his coaching drained his energies away from college lecturing and administration, he did find time to conduct original research, making 34 contributions to the journals in this study between 1857 and 1895. Although coaching clearly did not pay Routh to research, it also did not prevent the Adams Prize winner, creator of well-regarded textbooks, and member of several scientific societies from becoming "[a] commanding figure in the history of English mathematics."[84]

By the middle of the nineteenth century, college tutors at Cambridge had relinquished a large proportion of their educational duties to private coaches. The result of this transfer of educational power "was that the whole instruction of the bulk of the more advanced students (in mathematics) passed into the hands of a few men who were independent both of the university and the colleges — a fact which seems to be as puzzling as it is inexplicable to foreign observers."[85] At the same period in Oxford, college tutors were actively trying to regain from the coaches their position as the most effective teachers. As at Cambridge, the establishment at the beginning of the nineteenth century of competitive examinations for attaining honors and even the ordinary BA at Oxford had spawned private coaching.[86] In specializing instruction, adopting the teaching methods used by coaches, and strengthening their overall

[83]Rothblatt, p. 203.
[84]*Alumni Cantabrigienses*, s.v. "Routh, Edward John."
[85]Ball, p. 161.
[86]Engle, "Emerging Concepts," p. 307.

quality by easing restrictions on fellowship elections, college tutors at Oxford eventually reestablished control over the instruction of their students.[87] The percentage of "idle" fellows also sharply decreased from over 90% of the fellowship in 1814 to less than half by 1900.[88]

While private coaching existed at Trinity College, Dublin, tutors and the so-called "grinders" felt that their respective roles were complementary and did not wrestle over the control of their students. Coaches were seen a providing key services to those both needing remediation and aspiring to prizes and honors, including fellowship candidates.[89] Although college tutors at Dublin did not feel the need to reinvent themselves in order to compete with coaches, university reforms did alter their character and composition. A more balanced fellowship examination resulted in fellows with expertise in the classics and philosophy as well as mathematics. The number of these new junior fellows increased from 18 in 1830 to 27 by 1892; this increase, coupled with falling student enrollment, lessened the burdens of teaching.[90]

Coaching at Cambridge eventually began to cater to the two ends of the student spectrum as it did in Dublin; tuition for those students in the middle was increasingly handled inside the colleges. The establishment of intercollegiate instruction streamlined college tutoring, and, as at Oxford, the adoption of techniques from successful coaches improved the quality of college tuition.[91] With the lifting of celibacy re-

[87]Engle, *Clergyman to Don*, pp. 280-281.
[88]*Ibid.*
[89]McDowell and Webb, pp. 132-133.
[90]*Ibid.*, pp. 103, 231-232, 298, 322.
[91]Rothblatt, p. 230-231.

quirements at Cambridge and Oxford by the 1880s,[92] college posts were increasingly recognized as possible lifelong careers rather than as stepping stones to non-academic fields.

Besides college positions, university professorships provided employment for many nineteenth-century British mathematicians.[93] The expectations and influence of these posts varied widely from university to university. At the end of the eighteenth century, professors at Cambridge were chosen for their scholastic eminence instead of their teaching prowess, and "they were generally glad to abandon nearly all teaching to the colleges."[94] This attitude continued into the next century; for example, Charles Babbage continued to live in London while holding the Lucasian Professorship of Mathematics at Cambridge from 1828 to 1839 and gave no lectures.[95]

Unlike Babbage, Arthur Cayley tried to play an active role as a Professor at Cambridge. Elected to the first Sadlerian Chair of Pure Mathematics in 1863, Cayley joined a younger group of professors at Cambridge who saw themselves "as much bound to teach and write as any other salaried functionary is bound to discharge the duties for which he is paid."[96] In his post, Cayley was to give a course of lectures

[92]Leedham-Green, p. 168; and Engle, "Emerging Concepts," on p. 349.

[93]While they were actively contributing to the journals in this study, at least 157 of the domestic contributors here held 157 professorships in the mathematical sciences (pure and applied mathematics, astronomy, and natural philosophy or physics), five in engineering, 13 in other sciences (botany, experimental physics, chemistry, acoustics, electrotechnics, mechanism and applied mechanics, and geology), one in naval architecture, one in political economics, one in divinity, two in law, one in moral philosophy, and four in foreign or ancient languages (Latin, Greek, Hebrew, and oriental languages). If a professor changed positions, each position is counted separately above.

[94]Ball, p. 158.

[95]Hannabuss, "Mathematics," p. 446.

[96]Arthur Sidgwick and E.M. Sidgwick, *Henry Sidgwick, A Memoir* (London, 1909), p. 153; quoted in Rothblatt, p. 152.

spanning one term per year. Thus, he had no teaching requirements for more than three-fourths of each year. While he was teaching, Cayley, like the other Cambridge mathematical professors, could not be assured a substantial audience. Although regulations set in the 1860s required students to attend one course of lectures per year from one of a list of professors, this list did not include anyone in mathematics.[97] Unless their lectures would be directly beneficial to preparation for the Tripos, these professors could expect few students in attendance.[98]

During the nineteenth century, "[t]he leisure of a Cambridge professor to work at his research can be contrasted with his mathematical neighbour, the hard-driven Cambridge coach who worked himself (and his students) around the year."[99] This leisure promoted the research of the professor, but his alienation from teaching prevented him from training a new generation of researchers. One step towards forming a research relationship between students and professors at Cambridge occurred with new rules in 1883 that required that the Smith's prizes to be awarded on the basis of dissertations instead of examinations. Cayley and other professors, while not required to do so, advised students writing their prize essays "and with their support many distinguished research careers were launched."[100]

As in Cambridge, the statutory lectures delivered by Oxford professors were usually ill attended because the areas of the professorships were not part of the required

[97]Crilly, chapter 11, pp. 9-10.
[98]Rothblatt, p. 199.
[99]Crilly, chapter 11, p. 13.
[100]June Barrow-Green, "'A Corrective to the Spirit of Too Exclusively Pure Mathematics': Robert Smith (1689-1768) and his Prizes at Cambridge University" *Annals of Science* 56 (1999): 271-316 on p. 308.

curriculum.[101] On his election as Savilian Professor of Geometry in Oxford in 1827, Baden Powell was advised by a college administrator to focus principally on research instead of lecturing.[102] However, he became actively involved in lecturing, writing textbooks, and trying to improve the place of mathematics at Oxford, albeit with little success.[103] Like Powell, his successor in the chair of geometry, Henry Smith, also actively lectured as a Professor. Because of his weak financial status, Smith performed this university instruction alongside college lecturing at Balliol. With the additional administrative duties that Smith assumed as Keeper of the University Museum in 1874, the breadth of his international relations and the depth his mathematical research stand as impressive accomplishments.[104]

Despite these notable examples, professors at Oxford, while enjoying time for research, were isolated from the college tutors and students. Sylvester, who arrived in Oxford in 1883 to assume the Savilian Professorship of Geometry, was painfully aware of this isolation. Four years after leaving his professorship of mathematics at the Johns Hopkins University, from which he had led America's first mathematical research school for Oxford, Sylvester lamented to Hopkins President, Daniel Coit Gilman, that "I am out of heart in regard of my Professorial work in this University in which all the real power of influencing the studies of the place lies in the hands of

[101]Engle, "Emerging Concepts," p. 306.
[102]M.G. Brock, "The Oxford of Peel and Gladstone," *History of Oxford, Part I*, pp. 7-71 on p. 20.
[103]Hannabuss, "Mathematics," p. 446.
[104]Keith Hannabuss, "Henry Smith," in *Oxford Figures: 800 Years of the Mathematical Sciences*, ed. John Fauvel, Raymond Flood, and Robin Wilson (Oxford: Oxford University Press, 2000), pp. 203-217 on pp. 205-212. For more on Smith's international activity, see chapter 6. For more on his mathematical activity, see chapter 7.

the College Tutors and in which I can see no prospect of doing any real good."[105] The dominance of the college tutors at Oxford after the mid-nineteenth century resulted in a slow development in the number of professorships. While these posts grew from 18 in 1800 to 47 by 1900, they paled in comparison to the number of college positions and offered only limited opportunities for promotion among the fellows.[106]

Unlike most of those at Oxford, professors in the mathematical sciences at Trinity College, Dublin had a great influence on both the instruction and research directions of the university.[107] These men often came from the university's fellows, and taught subjects relevant to their students' examinations. Non-fellow professors, especially if their specialities were outside the curriculum, enjoyed little influence or remuneration in this institution "run by the Fellows for the Fellows and students."[108] They were seen as "technical experts hired to discharge specialized teaching duties, but not qualified to participate in the general direction of academic affairs."[109] At least one of the non-fellow professors, however, was not socially isolated from the fellows; William Rowan Hamilton maintained consistently good relations with them. However, the location of the Professor of Astronomy five miles away from the University at the Observatory at Dunsink isolated him geographically from his institution: "the work done by the other members of the school was almost entirely independent of Hamilton's, and the latter's influence on the scientific life of his own university was negligible during his

[105] J.J. Sylvester to Daniel Coit Gilman, 11 March 1887, in Parshall, *Life and Work* p. 263.
[106] Engle, "Emerging Concepts," pp. 305, 351.
[107] For more on the mathematics instruction at Dublin, recall chapter 4.
[108] McDowell and Webb, p. 310.
[109] *Ibid.*, p. 111.

lifetime."[110]

At institutions lacking the collegiate structure of Oxford, Cambridge, and Dublin, professors had no trouble attracting students to their lectures. However, their days were crowded with teaching, leaving little room for research. A student recalled the extensive teaching efforts of his Professor of Mathematics at University College, London, Augustus De Morgan:

> De Morgan was far from thinking the duties of his chair adequately performed by lecturing only. At the close of every lecture in each course he gave out a number of problems and examples illustrative of the subject which was then engaging the attention of the class. His students were expected to bring these to him worked out. He then looked them over, and returned them revised before the next lecture. Each example, if rightly done, was carefully marked with a tick, or if a mere inaccuracy occurred in the working it was crossed out, and the proper correction inserted. If however, a mistake of *principle* was committed, the words "show me" appeared on the exercise. The student so summoned was expected to present himself on the platform at the close of the lecture, when De Morgan would carefully go over the point with him privately, and endeavour to clear up whatever difficulty he experienced. The amount of labour thus involved was very considerable, as the number of students in attendance frequently exceeded one hundred.[111]

While many of De Morgan's efforts in teaching, encouraged by his defined pedagogical opinions, were self-imposed,[112] even a less conscientious professor would have strained under the responsibility of teaching the entire mathematics course at the University.

Before his stints at Hopkins and Oxford, Sylvester often complained of excessive teaching duties as Professor of Mathematics at the Royal Military Academy, Woolwich. Writing to the Vice-Principal of the Council of Military Education, Major-

[110] A.J. McConnell, "The Dublin Mathematical School in the First Half of the Nineteenth Century," *Proceedings of the Royal Irish Academy* 50 (1944-1945): 75-86 on p. 79.

[111] Sophia E. De Morgan, *Memoir of Augustus De Morgan* (London: Longmans, Green & Co., 1882), p. 99; quoted in Rice, "Mathematics in the Metropolis," pp. 380-381.

[112] Rice, "Mathematics in the Metropolis," pp. 381-382.

General Hamilton, Sylvester grumbled that "I doubt if my strength will be found eventually equal to the amount of work now called for and still more whether the wear and tear of an occupation so laborious and continuous... will not prove fatal to the elasticity of mind necessary to the successful prosecution of those scientific pursuits which I set before all pecuniary considerations."[113] Sylvester's view of himself "as a researcher and teacher (in that order)" conflicted with the Woolwich administration, and it was not until he arrived at Hopkins in 1876 that he would find a position rewarding in both roles.[114]

The professorships held by the domestic contributors rarely rewarded both research and teaching. For professors at the ancient English universities, there was ample time for research but a high probability of academic isolation and disenfranchisement. In contrast, other British universities offered ample student and administrative interaction at the cost of research. Despite these limitations, professors were able to stay in academia, an opportunity that several members of the nineteenth-century British mathematical community did not have.

For many in the clerical environments of Oxford, Cambridge, and Dublin, a church post represented the smoothest transition from a fellowship. For the overworked fellows of Trinity College, Dublin, a position in a parish provided an opportunity for the research which had been earlier stifled by tutorial work. Thomas Robinson, for example, produced from his parish at Armagh astronomical research for which he was

[113] J.J. Sylvester to Major-General Hamilton, 11 Feb. 1863, in Parshall, *Life and Work*, p. 117.
[114] Parshall, *Life and Work*, pp. 80, 137.

awarded the Royal Society's Royal Medal.[115]

Teaching or administration in secondary schools offered another logical transition for recent graduates. Of the 79 subjects engaged in secondary school teaching or administration while publishing mathematics in the journals considered here, over 40% contributed to the pedagogically focused *Proceedings of the Edinburgh Mathematical Society* or to the independent *Messenger of Mathematics.* Thomas Muir, as a teacher at Glasgow High School, contributed frequently and served as the second President of the Edinburgh Mathematical Society. Educators, however, did not limit their contributions to journals presenting mathematical pedagogy. Henry Jeffrey made 37 contributions to the research-focused *Quarterly Journal of Pure and Applied Mathematics* while serving as Master of the Cheltenham Grammar School.[116]

Sylvester and Cayley are notable examples of British mathematicians who worked outside academia while pursuing mathematical research. From 1844 to 1855, Sylvester served as an actuary with the Equity and Law Life Assurance Society, before gaining a Woolwich professorship. Similarly, in 1846, Cayley left his position as a Fellow at Trinity College, Cambridge and began law studies at Lincoln's Inn; he continued to practice law for almost two decades until his election to the Sadleirian Chair at Cambridge in 1863.[117] While these career paths today seem strange for two internationally respected mathematicians, their circumstances, however, were far from unique. Moreover, a substantial number of domestic contributors, unlike Sylvester

[115]McDowell and Webb, pp. 108-109.

[116]*Modern English Biography,* s.v. "Jeffery, Henry Martyn."

[117]For information on Cayley's career in law, see chapter 6. For Sylvester's tenure as an actuary, see Parshall, *Life and Work,* p. 2.

and Cayley, permanently left the university behind after graduation. James Cockle left Cambridge as 33rd Wrangler to study law at the Middle Temple in 1838. After a successful law career on the midland circuit, Cockle was called to be the first Chief Justice of Queensland, Australia in 1863. During his sixteen years in this position, he also served as the President of the Queensland Philosophical Society. After retiring to England, he served in the same role at the London Mathematical Society (LMS). More renowned as a mathematician than as a judge, Cockle produced seminal work on the theory of differential equations, and made many contributions to algebra.[118]

Another mathematician in what today would seem like a very non-mathematical profession was William Spottiswoode. The year after he graduated from Oxford with a first class in mathematics, Spottiswoode took over his father's business as printer to the Queen. While a printer, Spottiswoode served as President of both the LMS and the Royal Society and contributed 31 articles to the British journals of this study, including a very well-regarded series in the *Philosophical Transactions of the Royal Society of London* on the contact of curves and surfaces.[119]

While domestic contributors working outside of academia were not as numerous as those employed in college or university positions, the diversity of their occupations reveals that mathematicians in nineteenth-century Britain had no predetermined career path to follow. Indeed, the problems of incorporating both research and teaching into university positions indicates that mathematics as a paying job was at best a remote possibility for British mathematicians.

---

[118] *Dictionary of National Biography*, s.v. "Cockle, Sir James."
[119] *Dictionary of National Biography*, s.v. "Spottiswoode, William."

Society Activity among Domestic Contributors

With the paucity of jobs compensating mathematical research and the intellectual isolation facing those fortunate enough to gain these positions, it is not surprising that many domestic mathematical contributors actively participated in scientific societies. These societies offered intellectual and social interaction, encouragement of research, and publication opportunities.[120] Table 5D displays the society memberships of the domestic contributors to the journals considered here. Of these, half held memberships in at least one of the ten British general or specialized societies listed in the table below.[121] Those active in societies understandably formed a high proportion of the domestic contributors to society-supported journals. Among the latter, the *Proceedings* of the mathematical societies of London and Edinburgh had the highest percentage of "in-house" contributors: only 28 of the 138 domestic contributors to the journal of the LMS and 21 of the 73 domestic contributors to that of the EMS were not members of the journals' societies. While members of both of these societies tended to support their respective society's journal, they varied widely in their support of other mathematical publication venues. LMS members represented almost 40% of the domestic mathematical contributors to the *Philosophical Transactions of the Royal Society of London*, 46% of those to the *Quarterly Journal of Pure and*

[120]For more on the publication venues offered by scientific societies, recall chapter 2.

[121]The membership numbers presented above are probably understated because not all of the biographical sources consulted provided society information. Memberships lists were consulted for the LMS, Edinburgh Mathematical Society, and Royal Society of Edinburgh (although not all of these lists covered all the relevant years for the nineteenth century); thus, the figures for these societies may be considered as fairly accurate. Moreover, since a fellowship in the Royal Society of London was an honor not likely to be left off of any biography, the figures for this society are similarly accurate.

Table 5D: Society Memberships of Domestic Contributors

(Journal§ to which domestic mathematicians contributed)

	BA	*TC*	*MM*	*MP*	*TI*	*TE*	*PT*	*PR*	*PE*	*PL*	*MR*	*MN*	*PM*	*CM*	*CD*	*OC*	*Ms*	*QJ*	*Ly*	tot.♯
RSL	30	36	13	10	16	18	87	104	7	62	18	29	104	11	18	19	55	67	10	242
RSE	11	14	5	4	6	24	25	34	30	15	8	13	44	6	12	7	17	18	5	94
RIA	6	3	1	1	14	2	9	10	1	8	1	7	16	0	4	3	8	7	0	32
LMS	16	27	6	5	11	9	53	52	16	110	6	13	53	7	12	19	92	85	0	194
EMS	1	3	0	0	0	7	2	6	52	8	0	0	10	0	0	4	7	7	0	60
RAS	12	12	5	6	4	5	34	34	3	35	19	36	41	4	8	13	31	35	5	110
PS	3	3	0	1	0	1	6	10	0	10	0	1	12	0	0	3	8	8	0	25
CPS	13	28	2	3	3	7	34	33	3	40	6	10	30	6	8	7	39	35	0	74
MLP	3	2	8	4	1	2	8	7	0	8	1	2	10	1	3	4	8	8	0	16
AI‡	2	1	0	0	0	1	4	7	1	5	0	3	6	0	0	3	5	3	0	13
Mem*	33	49	17	11	24	30	102	125	61	119	23	49	152	15	28	33	108	108	12	440
%†	89%	75%	65%	79%	71%	75%	75%	63%	84%	86%	85%	77%	49%	58%	52%	51%	63%	59%	39%	50%

♯ This total represents the number of domestic members of a given society contributing to one or more of the journals above.

* This total represents the number of domestic contributors to a given journal who belonged to one or more of the ten societies above.

† Percentages are rounded to nearest 1%. These percentages represent the proportion of domestic contributors with a membership in one or more of the 10 societies above writing in the given column's journal out of all the domestic contributors to that journal.

§ *BA* = *Report of the BAAS*; *TC* = *Transactions of the Cambridge Philosophical Society*; *MM* = *Memoirs of the Manchester Lit. & Phil. Soc.*; *MP* = *Proceedings* of the Manchester Lit. & Phil. Soc.; *TI* = *Transactions of the Royal Irish Academy*; *TE* = *Transactions of the Royal Society of Edinburgh*; *PT* = *Philosophical Transactions of the Royal Society of London*; *PR* = *Proceedings of the Royal Society of London*; *PE* = *Proceedings of the Edinburgh Mathematical Society*; *PL* = *Proceedings of the London Mathematical Society*; *MR* = *Memoirs of the Royal Astronomical Soc.*; *MN* = *Monthly Notices of the Royal Astronomical Soc.*; *PM* = *Philosophical Magazine*; *CM* = *Cambridge Mathematical Journal*; *CD* = *Cambridge and Dublin Mathematical Journal*; *OC* = *Oxford, Cambridge, and Dublin Messenger of Mathematics*; *Ms* = *Messenger of Mathematics*; *QJ* = *Quarterly Journal of Pure and Applied Mathematics*; *Ly* = Leybourn's *Mathematical Repository*.

‡ RSL = Royal Society of London; RSE = Royal Society of Edinburgh; RIA = Royal Irish Academy; LMS = London Mathematical Society; EMS = Edinburgh Mathematical Society; RAS = Royal Astronomical Society; PS = Physical Society; CPS = Cambridge Philosophical Society; AI = Association for the Improvement of Geometrical Teaching.

Applied Mathematics, and over half of those to the *Messenger of Mathematics*. In contrast, members of the EMS tended to limit their publications to their own journal. This difference between the two mathematical societies may be explained in part by the fact that the *Proceedings* of the EMS, unlike the other journals in Table 5D, catered to those writing pedagogically oriented articles.

As noted in chapter 2 above, non-members who wanted to contribute to a society's journal usually had to find a society member willing to "communicate" the contribution.[122] Moreover, the manuscript, once "communicated," had to survive the refereeing process and, in case of the Royal Society, ran the risk of never being returned. Those not involved with societies could avoid these publication restrictions altogether by participating in independent journals. The percentages of society members among the domestic contributors to the seven independent journals in Table 5D is considerably lower than those for the society-supported journals. However, in each case, society members still accounted for more than half of these contributors.

Scientific society involvement provided opportunities for communication through meetings and publications for mathematicians overworked or isolated in universities and elsewhere. All but ten of the 92 most prolific domestic contributors to the journals here, in fact, held memberships in the societies listed in Table 5D. It is to a profile of these most prolific contributors that we now turn.

[122]Dwight Atkinson, *Scientific Discourse in Sociohistorical Context: The Philosophical Transactions of the Royal Society of London, 1675-1975* (Mahway, NJ: Lawrence Erlbaum Associates, 1999), p. 43.

Profile of the Most Prolific Domestic Contributors over the Century

Most domestic contributors made only brief forays into the world of mathematical publication. In fact, almost 40% of the contributors to our sample of journals actually made only one contribution and well over half made less than three. However, the 92 domestic contributors publishing 20 or more articles in the journals of this study buoyed the average number of contributions per contributor to 8.5 (See Table 5E).

Nathan Reingold encountered a similar situation— many publishing a little and a few publishing prolifically— among nineteenth-century American scientists. Reingold used these prolific contributors to estimate the number of what he called researchers as opposed to practitioners and cultivators.[123] While our group of prolific contributors, like Reingold's group of researchers, fails to recognize brilliant scientists who rarely published, and sometimes confuses quantity over quality,[124] in the absence of modern professional structures, it allows us to gain some conception of those committed to advancing mathematics.

In examinations, scientific society activity, and contemporary recognition, many

[123]Nathan Reingold, "Definitions and Speculations: The Professionalization of Science in America in the Nineteenth Century," in *The Pursuit of Knowledge in the Early American Republic*, ed. Alexandra Oleson and Sanborn C. Brown (Baltimore and London: The Johns Hopkins University Press, 1976), pp. 33-69 on p. 38. Reingold defines researchers as "individuals characterized by a single-minded devotion to research, resulting in an expertise yielding an appreciable accomplishment by past standards certainly and in retrospect in some instances." Practitioners are "individuals wholly or largely employed in scientific or science-related occupations. Those who publish are less prolific and less significant in terms of accomplishment than researchers." Finally, cultivators possess "learned culture," are not interested in publishing articles, but attend the meetings of local scientific societies. *Ibid.*, pp. 38-41. Della Fenster and Karen Parshall also found a similar situation in the American mathematical context. See Della Dumbaugh Fenster and Karen Parshall, "A Profile of the American Research Community: 1891-1906," in *The History of Modern Mathematics*, vol. 3, ed. Eberhard Knobloch and David E. Rowe (Boston: Academic Press, 1994), pp. 179-227, especially pp. 184-188; and the discussion of two prolific American contributors to British scientific journals in chapter 6.

[124]*Ibid.*, p. 60.

Table 5E: The Most Prolific Domestic Mathematical Contributors to Nineteenth-Century British Scientific Journals†

Contributor	#‡	Contributor	#	Contributor	#
Adams, J. C.	27	Gregory, D. F.	27	Powell, B	31
Airy, G. B.	74	Griffiths, J.	42	Rankine, W. J. M.	49
Allardice, R. E.	25	Hamilton, W. R.	66	Rawson, R.	21
Ball, R. S.	21	Hargreave, C. J.	66	Rayleigh, J. W. S.	89
Basset, A. B.	22	Harley, R.	27	Roberts, R. A.	27
Boole, G.	55	Hart, H.	20	Roberts, S.	71
Booth, J.	24	Heaviside, O.	21	Routh, E. J.	34
Brill, J.	26	Herschel, J. F. W.	22	Russell, W. H. L.	50
Bronwin, B.	45	Hicks, W. M.	22	Salmon, G.	39
Buchheim, A.	22	Hirst, T. A.	22	Smith, A.	22
Burnside, W.	63	Ivory, J.	85	Smith, H. J. S.	34
Casey, J	21	Jeffery, H. M.	56	Spottiswoode, W.	52
Cayley, A.	793	Johnson, A. R.	20	Steggall, J. E.	23
Challis, J.	123	Kelland, P.	27	Stokes, G. G.	57
Chree, C.	35	Kirkman, T. P.	60	Sylvester, J. J.	161
Clifford, W. K.	27	Knight, T.	22	Tait, P. G.	51
Cockle, J.	91	Larmor, J.	32	Tanner, H. W.	52
Darwin, G. H.	43	Love, A. E. H.	21	Taylor, C.	40
Davies, T. S.	41	Lubbock, J. W.	63	Taylor, H. M.	31
De Morgan, A.	81	Mackay, J. S.	32	Thomson, J. J.	22
Dixon, A. C.	22	MacMahon, P. A.	44	Thomson, W.	101
Drach, S. M.	21	Mathews, G. B.	32	Townsend, R.	36
Elliott, E.B.	40	Maxwell, J. C.	32	Tucker, R.	39
Ellis, R. L.	33	Merrifield, C. W.	32	Walker, J. J.	48
Ferrers, N. M.	41	Moon, R.	30	Wallace, W.	29
Forsyth, A. R.	51	Moseley, H.	20	Walton, W.	102
Frost, P.	31	Muir, T.	52	Warren, J. W.	24
Genesé, R. W.	22	Muirhead, R. F.	23	Whitworth, W. A.	39
Gibson, G. A.	21	Murphy, R.	20	Wolstenholme, J.	26
Glaisher, J. W. L.	296	Pearson, K.	46	Young, J. R.	41
Greenhill, A. G.	47	Peddie, W.	20		

† The titles of these journals are listed at the beginning of this chapter.

‡ "#" means the number of contributions a given contributor made to these journals while the contributor lived in Britain. If the contributor wrote for some time from outside of Britain, those contributions are counted as foreign and are not counted here. See chapter 6.

of these prolific contributors were leaders. Of the 51 educated at Cambridge, all but one graduated as Wranglers, 28 finished as Smith's Prizemen, and 41 were elected to fellowships. In addition to preparing articles for publication, 32 served as presidents of a variety of scientific societies, and 14 served in this position at the LMS. A variety of scientific societies, in turn, bestowed their medals on 31 of the 92 prolific mathematicians. On top of society awards, 50 members of this group were recognized with entries in the *Dictionary of National Biography.*

At some point during their publication careers, all but nine of these contributors were affiliated with universities or colleges as students, fellows, tutors, lecturers, professors, or administrators. The fact that 50 of these affiliations were professorships indicates that these academic ties were maintained for the entire productive lives of many in this group. As described above, the responsibilities of these professors varied widely from institution to institution.

A Cambridge professor held the distinction as the most prolific contributor in this group. Arthur Cayley, who published over 790 articles in the journals of this study, certainly used the leisure afforded by his position to conduct research.[125] However, before assuming his professorship and while working in the more hectic world of law, Cayley still managed to publish around 300 articles, which incorporated "some of his best and most original work."[126]

Glaisher, in contrast to Cayley, never left Cambridge, and found time from his duties as a college tutor and lecturer to be extremely active in a variety of scientific societies, to edit journals, and to publish 296 articles in this study's journals, a

[125]Cayley also contributed hundreds of mathematical articles to foreign journals. See chapter 6. His *Collected Mathematical Papers* contain 967 articles.

[126]Charles Coulston Gillispie, ed., *Dictionary of Scientific Biography*, 16 vols. 2 supps. (New York: Charles Scribner's Sons, 1970-1980), s.v. "Cayley, Arthur."

number second only to Cayley. Although he was recognized as "one of the outstanding English pure mathematicians" while in the prime of life,[127] the overall quality of his contributions was not as consistent as that of Cayley.[128]

William Burnside, who made 63 nineteenth-century contributions to the journals in this study, was trained in but worked outside of the Cambridge university sphere. He, in fact, declined an offer to return to Pembroke College, Cambridge, and instead remained the Professor of Mathematics at the Royal Naval College at Greenwich. His duties, which included instructing naval officers in ballistics, engineering topics, and dynamics, proved to be "to his liking. It was a [*sic.*] round, well-defined in extent and in demands on time, within a variety of congenial subjects, though only touching in part upon the regions of his constructive thought... It also left him leisure, which was carefully and diligently used, to pursue his own researches."[129] While he maximized his leisure time for research, he adopted a concise writing style and avoided the discussion of tangential issues.[130] As a result, during his tenure at Greenwich, which encompassed all but the first two years of his nineteenth-century publication life, he was able to produce a variety of high quality work, including the work on the theory of groups for which he is best known today.

Henry Tanner, like Burnside, was a superb time manager and produced 52 contributions to the journals in this study. While he showed mathematical promise at

[127] *Dictionary of National Biography*, s.v. "Glaisher, James Whitbread Lee."

[128] For more on Glaisher's editorial efforts and his mathematical contributions, recall chapter 4. For his society involvement, recall chapter 2.

[129] "William Burnside — 1852-1927," *Proceedings of the Royal Society of London*, ser. A, 117 (1928): xi-xxv on p. xii.

[130] Ibid., pp. xv-xvi.

Oxford, Tanner "did not allow to himself that the circumstances of the moment called for ... the cultivation of examination facility."[131] Thus, he was bypassed for Oxford's scholarships and fellowships, and eventually accepted a Professorship of Mathematics and Physical Science at Cirencester's Royal Agricultural College. This institution provided "congenial and not too burdensome duties, with sufficient leisure for research;"[132] however, political strife at the College ultimately left Tanner without a job in 1880. A "life of vast usefulness" awaited him at the newly founded University College of South Wales and Monmouthshire.[133] In the Chair of Mathematics and Astronomy from 1883 to 1909, Tanner established the College's program of mathematical studies, which provided little opportunity "for the exercise of his gifts in fostering higher study."[134] Despite this responsibility and the lack of intellectual stimulation in his work, Tanner produced well-regarded research in differential equations and number theory.

Unlike the mathematicians just considered, Samuel Roberts worked outside academia while publishing numerous mathematical articles. After obtaining an MA from the University of London in 1849, Roberts began a career in law. On retiring from his practice to live in London and with the foundation of the LMS, Roberts found the time and inspiration to produce mathematical innovations.[135] To the LMS, he both

[131] "Henry William Lloyd Tanner, 1851-1915," *Proceedings of the Royal Society of London*, ser. A, 91 (1915): lxix-lxxiv on p. lxix.
[132] *Ibid.*
[133] *Ibid.*, p. lxx.
[134] *Ibid.*
[135] "Samuel Roberts, 1827-1913," *Proceedings of the London Mathematical Society*, ser. A, 89 (1914): xx-xxi on p. xx.

devoted administrative energy and contributed significant articles; Roberts also maintained mathematical correspondence with fellow society members including Cayley, Sylvester, De Morgan, and Salmon.

One of Roberts's biographers reflected that "[t]hroughout his life he was of a retiring disposition and regarded original research as being its own reward."[136] This same evaluation could most likely have been made of the majority of this prolific group of domestic contributors. Their devotion to mathematics helped them to make time for research, even when no time was made for research in their jobs. The occupations of these contributors might have allowed "leisure," but this time was not specified for research; it could have been spent collecting pottery or cultivating an interest in fishing rather than pursuing mathematics. Without an institutional structure encouraging original work, the accomplishments of this prolific group reflect a deep commitment to furthering mathematics.

Conclusion

In his considerations of science in universities, J.B. Morrell listed six features that appeared prominently in the process of transformation of nineteenth-century science "from a pastime of leisured and wealthy individuals into a regular vocational pursuit."[137]

> First, the number of full-time paid positions that were directly or indirectly connected with the possession of scientific knowledge increased... [Second]

[136] *Ibid.*, p. xxi.

[137] J.B. Morrell, "Science in the Universities: Some Reconsiderations," in *Solomon's House Revisited: The Organization and Institutionalization of Science*, ed. Tore Frängsmyr (Canton, MA: Science History Publications, 1990), pp. 51-64 on p. 51.

> was the establishment of specialist qualifications that functioned as public certification of scientific competence... Third, training procedures were developed... Fourth, in research publications there was a rapid growth of specialization as different areas of science detached themselves not only from polite culture, but from the republic of science... Fifth, those who studied the natural world increasingly felt self-consciousness about their identity... Last, various reward systems were developed.[138]

To varying degrees, these six factors surface in this prosopography. Specialization in research publications, for example, has been documented throughout the chapters above. Another factor, the foundation of qualifications for mathematicians can be seen in the late nineteenth-century establishment in British universities of degrees awarded for research in mathematics. Similar research requirements for the Smith's prizes at Cambridge reflect the beginning of a system for training mathematical researchers. Burgeoning numbers of positions for mathematicians in British universities and colleges reflect a growth of paid occupations tied to mathematical knowledge. The active involvement of the domestic contributors in mathematical societies represents a growing awareness of their identity as mathematicians. Finally, the recognition received by the domestic contributors in the form of honorary degrees and society medals indicates the establishment of reward systems.

After describing these six features, Morrell warned that "it is tempting to see these six features as showing that in the nineteenth century science became a profession. But detailed investigation[s show]... the limitations of such an approach."[139] Morrell's features and his warning are relevant to the situation surrounding the late nineteenth-

[138] *Ibid.*, p. 51-52.
[139] *Ibid.*, p. 52.

century domestic contributors to the mathematical publication community as well.[140]

Nineteenth-century British mathematics was not professional in the sense that we know it today. For example, while we think of the professorship of mathematics as the model career of a professional mathematician, in nineteenth-century Britain, this position often entailed intellectual isolation or heavy teaching duties that left little time for research. Shapin and Thackray pointed out that "[t]he professionalization of the pursuit of abstract natural knowledge was never a goal of eighteenth or nineteenth century politicians or government. Britain remained the land of the scientific 'amateur' *par excellence*... The 'modern' separation of scientific culture... [from] the generally literate proceeded at a slower pace, and to a greater expression of general regret [in Britain]."[141] This perception also applies to nineteenth-century mathematics in Britain. Undergraduate studies, especially at Cambridge, could be stressful and circumscribed. After graduation, finding employment which allowed sufficient time for mathematical research was an unending struggle for most of these domestic contributors. However, it cannot be said that there did not exist a spirit of encouragement for original mathematical research that extended well beyond the defined professional limits of today.

---

[140]For other reviews of professionalization, see Roy Porter, "Gentlemen and Geology: The Emergence of a Scientific Career, 1660-1920," *The Historical Journal* 21 (1978): 809-836; and Reingold.
[141]Shapin and Thackray, p. 5.

Chapter 6: International Influences within the British Mathematical Publication Community

Gaining Access to the International Arena

During the first meeting of the British Association for the Advancement of Science in 1831, the President, Charles William, Viscount Milton, assessed Britain's international scientific connections as weak and called for them to be strengthened:

> In our insular and insulated country, we have few opportunities of communicating with the cultivators of science in other parts of the world. It is the more necessary, therefore, to adopt means for opening new channels of communication with them, and at the same time of promoting a greater degree of scientific intercourse among ourselves.[1]

Viscount Milton's sentiments were echoed in the pages of British mathematical journals. Duncan Gregory, founder of the *Cambridge Mathematical Journal*, aspired in 1837 to broaden his readers' exposure to international mathematics "by publishing the abstracts of important and interesting papers that have appeared in the Memoirs of foreign Academies."[2] Almost 20 years later, the editors of the *Quarterly Journal of Pure and Applied Mathematics*, which included Sylvester, Cayley, Stokes, and Hermite, underscored the importance of exposure to and participation in international mathematics: "it would be little credible to English Mathematicians that they should stand aloof from the general movement, or else remain indebted to the courtesy of

[1]Charles William, Viscount Milton, *Report of the British Association for the Advancement of Science* 1 (1831): 15-17 on p. 16. An earlier version of this chapter appeared as Sloan Evans Despeaux, "International Mathematical Contributions to British Scientific Journals, 1800-1900," in *Mathematics Unbound: The Evolution of an International Mathematical Research Community, 1800-1945*, ed. Karen Hunger Parshall and Adrian C. Rice (Providence: American Mathematical Society and London: London Mathematical Society, 2002), pp. 61-87.

[2]Duncan Gregory, "Preface," *Cambridge Mathematical Journal* 1 (1837): 1-2 on p. 1.

the editors of foreign journals for the means of taking a part in the rapid circulation and interchange of ideas by which the present era is characterised."[3]

The passages above reveal that by the middle third of the nineteenth century, British mathematicians expressed a need and a will to enter the international mathematical arena. This chapter explores the extent of internationalization in the British mathematical publication community through an analysis of foreign mathematical contributions to British scientific journals. This analysis reveals a small but important group of British mathematicians who actively promoted international interaction as well as the foreign mathematicians who responded to their encouragement. Moreover, an investigation of the factors that encouraged foreign mathematicians to contribute, the types of contributions these mathematicians made, and the groups they represented indicates a slow but steady international recognition of Britain as supporting a viable mathematical community.

This chapter also considers the range of British participation in the international mathematical publication community through a parallel analysis of British mathematical contributions to scientific journals outside of Britain. The number and types of papers presented by British mathematicians to these journals characterize the role of foreign publication in nineteenth-century British mathematics. Moreover, the isolation of educational, societal, and personal circumstances which motivated British mathematicians to present their work to foreign journals highlights limited but concentrated groups of mathematicians committed to developing and strengthening in-

[3] James Joseph Sylvester, *et al.*, "Address to the Reader," *Quarterly Journal of Pure and Applied Mathematics* 1 (1855): i-ii.

ternational mathematical ties with Britain.

International Mathematical Contributors to British Scientific Journals

A representative sample of 21 British scientific journals located international members of the British mathematical publication community. This sample included general scientific society publications, such as the *Philosophical Transactions* and *Proceedings of the Royal Society of London*, specialized society serials, such as the *Proceedings of the London Mathematical Society*, and general and specialized independent journals, such as the *Philosophical Magazine* and the *Quarterly Journal of Pure and Applied Mathematics*.[4] Over half of the journals in this sample contain consistent direct contributions from foreign mathematicians.[5] The overall increase in the number of foreign contributors and contributions to these journals throughout the nineteenth

[4]These 21 journals, grouped by content and sources of support and listed with their years of existence, are as follows: general scientific society periodicals — British Association for the Advancement of Science *Report* (1831-present); Cambridge Philosophical Society *Transactions* (1822-1928); Manchester Literary and Philosophical Society *Memoirs* (1785-1887), *Proceedings* (1857-1887), *Memoirs and Proceedings* (1888-present); Royal Irish Academy *Transactions* (1787-1907), *Proceedings* (1836-present); Royal Society of Edinburgh *Transactions* (1783-present); Royal Society of London *Philosophical Transactions* (1665-present), *Proceedings* (1832-present) — specialized society periodicals — Edinburgh Mathematical Society *Proceedings* (1883-present); London Mathematical Society *Proceedings* (1865-present); Royal Astronomical Society *Memoirs* (1822-present), *Monthly Notices* (1827-present) — independent general scientific journals — *Philosophical Magazine* (1798-present) — independent mathematical journals — *Cambridge Mathematical Journal* (1837-1845); *Cambridge and Dublin Mathematical Journal* (1846-1854); *Leybourne's Mathematical Repository* (1806-1835); *Oxford, Cambridge, and Dublin Messenger of Mathematics* (1862-1871); *Messenger of Mathematics* (1871-1929); and *Quarterly Journal of Pure and Applied Mathematics* (1855-1927).

[5]Table 6A contains 14 of the original 21 journals studied (in this table, the information for the "Report" and "Transactions" sections of the *British Association for the Advancement of Science Report* is listed separately). The seven journals not included either had no direct foreign contributions or had such contributions only in one volume (such as the *Transactions of the Royal Irish Academy* or the *Transactions of the Cambridge Philosophical Society* whose 1899 volume received several foreign contributions resulting from the jubilee held in honor of Stokes's fiftieth year in the Lucasian Professorship). A journal received "consistent direct contributions," if it received original foreign contributions for more than one volume. Unlike chapters 2 and 7, this chapter considers the "Transactions" sections of the *British Association for the Advancement of Science Report* because, although many of the articles there are only abstracts, they do give a sense of international participation in the society.

century reflects a growing international presence in this publication medium (see Table 6A[6]).[7] However, consistent growth was not the rule for individual journals; the exclusively mathematical journals fueled the general trend of growth, while the majority of general science journals in Table 6A experienced no significant increase in the number of foreign mathematical contributions over the century.[8] The stagnation of foreign mathematical contributions to these general scientific society journals, simultaneous with the growth of such contributions to mathematical journals, indicates a trend of specialization in mathematics publication in Britain.

Even among the exclusively mathematical journals, this growth was uncertain and sometimes checked. For example, while the *Quarterly Journal for Pure and Applied Mathematics* contained 13 foreign contributions in its first volume (1855-1856), it would require the next five volumes (1857-1862) to match this number of foreign articles; in fact, no other single nineteenth-century volume of the *Quarterly Journal* contained 13 or more foreign contributions. Several of the foreign contributions

[6]The nationalities of some of the authors in these journals was not determined. Thus, while these tables are as accurate as possible, they could underestimate the actual foreign activity in British journals, and British participation in foreign journals.

[7]While counts of scientific papers have been advocated by Derek de Solla Price as a good gauge of scientific activity, other sociologists have argued that citation counts, co-citation counts, or citation typing represent better measures. For reviews and criticisms of these techniques, see Henry G. Small, "The Lives of a Scientific Paper," in *Selectivity in Information Systems: Survival of the Fittest*, ed. Kenneth S. Warren (New York: Praeger Science Publishers, 1985), pp. 83-97; Daryl E Chubin and Soumyo D. Moitra, "Content Analysis of References: Adjunct or Alternative to Citation Counting?," *Social Studies of Science* 5 (1975): 423-441; and David Edge, "Quantitative Measures of Communication in Science: A Critical Review," *History of Science* 17 (1979): 102-134. Because of the absence of a citation database such as the *Science Citation Index* for the nineteenth century, I did not use citation counting in this analysis. However, I have looked for references to British mathematicians in the citations in the foreign contributions considered. See Table 6E.

[8]Contributions to both the *Philosophical Magazine* and the *British Association for the Advancement of Science Report* did grow over the century.

Table 6A: Foreign Contributors and Contributions by Decade: 1800-1900											
	Foreign Direct Contributors/Contributions (# : #)										
Journal	1800 - 1809	1810-1819	1820-1829	1830 - 1839	1840-1849	1850-1859	1860-1869	1870-1879	1880-1889	1890-1900	**1800-1900**
P.T.R.S. Lond.							2:3			2:2	**4:5**
Phil. Mag.	2:7	1:1	2:3	4:4	2:2	6:9	13:40	15:29	19:29	19:47	**79: 171**
Trans. R. S. Edin.								1:3	3:4	2:3	**3:10**
Mem. R. Astro. S.			4:4	1:1	1:1	2:2	1:3	2:2	1:1	1:2	**11:16**
Monthly Not. R. Astro. S.				2:3	2:4	10:12	7:17	11:14	3:3	5:10	**35:63**
Proc. R. S. Lond.				2:3	1:1	2:3	2:3	4:5	8:9	4:5	**23:29**
B A A S *Rep.*				1:1	1:3	1:1		3:2*	3:3	5:5	**13:15**
B A A S *Tran.*					2:2	3:5	5:5	7:12	12:15	9:10	**33:49**
Ca.. & Du. Math. J.					5:6	7:9					**9:15**
Manch. Proc.							1:7	1:1			**1:8**
Quart.J. Pure & Appl. Math.						9:21	7:19	11:25	8:12	17:35	**40: 112**
Proc. LMS							1:1	6:10	12:15	16:31	**32:57**
OCD Mess. Math.							3:8	2:3			**3:11**
Mess. Math.								14:64	17:37	13:41	**34: 142**
Proc. EMS									4:7	13:19	**15:26**
Total	2:7	1:1	6:7	9:12	12:19	34:62	36: 106	60: 170	67: 135	78: 210	**244: 729**

* In 1872, A. Erman (1806-1877) and H. Petersen (1815- ?) wrote "Report on the Gaussian Constants for the year 1829" together.

to the journal's first volume are in the form of correspondence to its editors or responses to the editors' work.

As an editor of the *Quarterly Journal*, the French mathematician Hermite naturally supported the journal with articles.[9] Two of his contributions to the first volume consist of letter extracts to Sylvester and Cayley. In the letter to Sylvester, Hermite proposed a method for finding a complete system of positive integer solutions to the equation $ax + by = n$, where a and b are positive integers with no common divisors.[10] The letter to Cayley concerned cubic forms; to the same number of the *Quarterly Journal*, Hermite included his article, "Sur les formes cubiques à deux indéterminées," on the same subject.[11]

Enrico Betti of the University of Pisa in Italy also presented results to the *Quarterly Journal* through correspondence. In a letter to Sylvester, Betti extended the solution of a problem first posed by Niels Henrik Abel, then reposed by Leopold Kronecker to the Academy of Berlin in 1853. The problem, finding the most general algebraic function that satisfies a given equation of a given degree, was solved by Kronecker for prime degrees. In his letter, Betti announced a solution of the problem for degrees that are powers of primes and provided a sketch of the proof.[12] However,

[9]Besides his work with the *Quarterly Journal*, Hermite published in the *Cambridge and Dublin Mathematical Journal* (see chapter 4 about his most notable contribution to this journal), the *Proceedings of the Royal Society of Edinburgh*, the *Proceedings of the LMS*, the *BAAS Report*, and the *Messenger of Mathematics.*

[10]Charles Hermite, "Extract of a Letter from M. Hermite to Professor Sylvester," *Quarterly Journal of Pure and Applied Mathematics* 1 (1855): 370-373.

[11]Charles Hermite, "Correspondence: Mr. Cayley and M. Hermite on Cubic Forms," and "Sur les formes cubiques à deux indéterminées," *Quarterly Journal of Pure and Applied Mathematics* 1 (1855): 88-89; 20-22.

[12]Enrico Betti, "Extract from a Letter of Signor Enrico Betti to Mr. Sylvester," *Quarterly Journal of Pure and Applied Mathematics* 1 (1855): 91-92.

he chose the inaugural volume of the *Annali di matematica pura ed applicata*, of which he was an editor, for the complete demonstration of his solution.[13]

Besides letter extracts, the first volume of the *Quarterly Journal* also contained original articles from foreign mathematicians. Francesco Brioschi, Professor of Applied Mathematics at the University of Pavia, had previously contributed to the *Cambridge and Dublin Mathematical Journal* and actively read and responded to articles in the *Quarterly Journal.* In his first *Quarterly Journal* contribution, in the inaugural volume in 1855, he used the determinant of functions to solve a differential equation that he had found in an article in the *Cambridge and Dublin Mathematical Journal* by University of Upsala Professor, Carl Johann Malmsten.[14] In his second article, Brioschi used determinants to prove two theorems in analytic geometry stated by Cayley in the first number of the *Quarterly Journal.*[15] Brioschi's support of communication via periodicals is reflected in his role in the 1858 foundation of the *Annali di matematica pura ed applicata* and in his place on the journal's editorial staff for the rest of his life.[16]

Although Brioschi's participation represented active communication through reading and responding to articles in the *Quarterly Journal*, his contributions were not extensive expositions. The majority of the foreign contributions to the inaugural vol-

[13]Enrico Betti, "Sopra l'equazioni algebriche con più incognite," *Annali di matematica pura ed applicata* 1 (1858): 1-8.
[14]Francesco Brioschi, "Sur une propriété d'un déterminant fonctionnel," *Quarterly Journal of Pure and Applied Mathematics* 1 (1855): 365-367.
[15]Francesco Brioschi, "Note sur deux théorèmes de géométrie," *Quarterly Journal of Pure and Applied Mathematics* 1 (1855): 368-370.
[16]Charles C. Gillispie, ed. *Dictionary of Scientific Biography*, 16 vols. and 2 supps. (New York: Charles Scribner's Sons, 1970-1990), s.v. "Brioschi, Francesco."

ume of the *Quarterly Journal* were short notes; in fact, only two exceeded six pages in length. Reinhold Hoppe, Privatdozent at the University of Berlin, provided one of these exceptions. In his article, "Determination of the Motion of Conoidal Bodies through an Incompressible Fluid," Hoppe contributed the only applied mathematical article to the first volume of the *Quarterly Journal.* In this paper, Hoppe considered a body moved by a given force through an incompressible fluid. He deemed this case as one "where the agreement between natural and analytic functions is so perfect, that the latter seem to exist exactly for the purpose to answer every question that can be proposed with regard to a certain motion of a fluid."[17] With the exception of two articles, the foreign contributions to the inaugural volume of the *Quarterly Journal* have the appearance of mere wishes for the journal's success rather than full-fledged research contributions.

While editorial influence spawned foreign mathematical contributions, so too did controversy. For example, almost half of the foreign mathematical contributions to the *Monthly Notices of the Royal Astronomical Society* from 1850 to 1869 consisted of a series of articles from 1859 to 1861 concerning the secular acceleration of the mean motion of the moon;[18] these articles chronicled a controversy that has been called "one of the largest and most active of the [nineteenth] century."[19] The cata-

[17]Reinhold Hoppe, "Determination of the Motion of Conoidal Bodies Through an Incompressible Fluid," *Quarterly Journal of Pure and Applied Mathematics* 1 (1855): 301-315.

[18]These 12 articles are from three foreign contributors; foreign contributions on lunar theory continued to appear in the *Monthly Notices* throughout the rest of the nineteenth century.

[19]David Kushner, "The Controversy Surrounding the Secular Acceleration of the Moon's Mean Motion," *Archive for History of Exact Sciences* 39 (1989): 291-316 on p. 291. Kushner's article provides a good discussion of this controversy in several national and political contexts.

lyst for this debate was John Couch Adams. Adams began his career in astronomy by co-discovering Neptune with Urbain Le Verrier, was President of the Royal Astronomical Society from 1851 to 1853, and soon after turned his attention to lunar theory.[20] In 1853, in the *Philosophical Transactions of the Royal Society of London,* he presented his calculation of the series for the acceleration of the moon's mean motion. The series yielded a value almost half as small as those previously calculated by the Royal Astronomer to the Observatory of Turin, Giovanni Plana,[21] and by Peter Andreas Hansen, head astronomer at the Observatory of Seeberg.[22] In 1856, Plana accepted Adams's results but then soon refuted them with calculations that also differed from Plana's original values; in 1859, Charles-Eugène Delaunay corroborated Adams's values through an independent method and communicated his findings to the Paris Academy.[23] Delaunay, a chief engineer at the École des Mines who later succeeded Le Verrier as director of the Paris Observatory, produced these results as part of a comprehensive investigation of lunar theory that he had begun in 1846.[24]

This lunar theory controversy did not end with Delaunay's corroborating results. One of the most persistent opponents of these results, Phillipe Gustave Doulcet,

[20] *Dictionary of Scientific Biography,* s.v. "Adams, John Couch." Adams was again President of the Royal Astronomical Society from 1874 to 1876, and became Lowndean Professor of Astronomy and Geometry at Cambridge in 1858. *Ibid.*

[21] *Dictionary of Scientific Biography,* s.v. "Plana, Giovanni."

[22] "Obituary: Peter Andreas Hansen," *Monthly Notices of the Royal Astronomical Society* 35 (1875): 169-170. Hansen became an Associate of the Royal Astronomical Society in 1837 and received the Society's Gold Medal in 1842 and 1860.

[23] "Obituary: John Couch Adams," *Monthly Notices of the Royal Astronomical Society* 53 (1893): 184-209 on p. 196.

[24] "Obituary: Charles Eugène Delaunay," *Monthly Notices of the Royal Astronomical Society* 33 (1873): 203-209 on pp. 204-207. These investigations appeared in the two-volume work, *La théorie de la lune,* published in 1860 and 1867. On the basis of this work, Delaunay was elected an Associate of the Royal Astronomical Society in 1862 and awarded the Society's Gold Medal in 1870.

Comte de Pontécoulant, repeatedly attacked these findings from 1859 to 1861. Described by Ivor Grattan-Guinness "as an outsider algebraist of the French mathematical community,"[25] Pontécoulant disagreed with the results of Adams and Delaunay because they disagreed with observations. In an 1859 article to the *Monthly Notices of the Royal Astronomical Society*, he claimed this disparity made "the existence of the new terms introduced by M. Adams *very problematic*."[26] Other astronomers shared Pontécoulant's misgivings. In the same number of the *Monthly Notices*, Hansen wrote that while he could not at that instant find the error in Delaunay's calculations, "I must determine to deem [them] as incorrect."[27] Through a grant from the British government, Hansen had published his lunar tables in London in 1857. In 1860, during a presentation to the French Academy, Le Verrier asserted that these tables refuted Delaunay's conclusions:

> Now the theory of M. Hansen agrees with them all, and one demonstrates to M. Delaunay that, with his formulas, one does not reach such agreement. Thus, doubts remain, and more than doubts relative to M. Delaunay's formulas. Most certainly, truth is on the side of M. Hansen.[28]

In a reply to those who disagreed with his results, Adams emphasized "that the

[25]Ivor Grattan-Guinness, *Convolutions in French Mathematics, 1800-1840*, 3 vols., *The Turns* (Basel: Birkhäuser Verlag, 1990), 2: 1204.

[26]Phillipe Gustave Doulcet, Comte de Pontécoulant, "Sur la variation séculaire du moyen mouvement de la lune," *Monthly Notices of the Royal Astronomical Society* 19 (1859): 235-236 on p. 236. "Cette conséquence seule paraîtrait déjà rendre *très problématique* l'existence des nouveaux termes introduits par M. Adams."

[27]Peter Andreas Hansen, "Extract of a Letter from Prof. Hansen to the Astronomer Royal, dated Gotha, May 31, 1859," *Monthly Notices of the Royal Astronomical Society* 19 (1859): 236-237 on p. 236. "Delaunay's Säcularänderung der mittleren Mondlänge muss ich entschieden für unrichtig halten."

[28]Urbain Jean Joseph Le Verrier; quoted in "Obituary: John Couch Adams," p. 197. "Pour un astronome, la première condition est que ses théories satisfassent aux observations. Or la théorie de M. Hansen les représente toutes, et l'on prouve à M. Delaunay qu'avec ses formules on ne saurait y parvenir. Nous conservons donc des doutes et plus que des doutes sur les formules de M. Delaunay. Très certainement la vérité est du côté de M. Hansen."

question is a purely mathematical one, with the decision of which observation has nothing whatever to do."[29] Moreover, he argued that causes not accounted for in the theory of the mean motion of the moon explained differences between his findings and observations.[30] By 1861, Adams's British colleagues, Cayley, William Donkin, and Sir John Lubbock, had arrived at Adams's results by a variety of methods;[31] moreover, by this time Plana had reached the same conclusions, and Hansen had acknowledged his agreement with them in the *Monthly Notices*.[32] However, Pontécoulant continued to attack these results into 1863, calling them "steeped in inacurracy,"[33] and he never accepted them.[34]

Through the multiple arguments concerning this controversy that they published in the *Monthly Notices of the Royal Astronomical Society*, Pontécoulant and Hansen became two of the most prolific foreign mathematical contributors in this analy-

[29] John Couch Adams, "Reply to Various Objections Which Have Been Brought against His Theory of the Secular Acceleration of the Moon's Mean Motion," *Monthly Notices of the Royal Astronomical Society* 20 (1860): 225-240 on p. 226.

[30] In 1865, Delaunay correctly suggested that the slowing of the earth's rotation due to tidal friction represented the unrecognized cause of the discrepancy between theory and observation. A year before, the American, William Ferrel, who would later contribute to British journals, was the first to treat this tidal friction quantitatively in a paper to the American Association for the Advancement of Science. *Dictionary of Scientific Biography*, s.v. "Delaunay, Charles-Eugène" and "Ferrel, William." Tidal retardation, while recognized in the eighteenth century, was again brought to light in 1848 by J. R. Mayer. An English translation of his essay on the subject was published in 1863 in the *Philosophical Magazine*. See Kushner, p. 306.

[31] "Obituary; John Couch Adams," pp. 197-198.

[32] Peter Andreas Hansen, "From a Letter from Professor Hansen to the Astronomer Royal, dated Gotha, 1861, Feb. 2," *Monthly Notices of the Royal Astronomical Society* 21 (1861): 152-155 on p. 154.

[33] Phillipe Gustave Doulcet, Comte de Pontécoulant, "Méchanique céleste: Observations sur la comparison établie par M. Delaunay entre les expressions des coordonnées de la lune déduites de sa théorie avec celles qui avaient été obtenues antérieurement," *Monthly Notices of the Royal Astronomical Society* 23 (1863): 259-266 on p. 260. "[P]lusieurs des résultats qu'il [M. Delaunay] présente peuvent être avec raison regardés comme entachés d'inéxactitude."

[34] "Obituary; John Couch Adams," p. 198.

sis.[35] While certainly not as prolific as Pontécoulant and Hansen, other foreign contributors generally did publish multiple mathematical contributions to British journals; on average, these journals contain 3 articles per foreign contributor.[36] In their study of nineteenth-century mathematics through the *Catalogue of Scientific Papers of the Royal Society of London*, Roland Wagner-Döbler and Jan Berg calculated that each mathematical contributor published in total an average of 6.48 articles in all nineteenth-century journal outlets covered by the *Catalogue*.[37] Presumably, authors who contributed to foreign journals wrote more extensively than those who published only in local journals; however, these two averages indicate that, in general, the number of foreign mathematical papers these authors contributed to British journals was not trivial.

The small but increasing numbers of foreign mathematical contributions to British journals over the nineteenth century imply a growing international presence within the British publication community. However, when viewed by the proportion of pages these contributions occupied among the total number of mathematical pages in British

[35]14 out of the 244 foreign contributors in this study made nine or more nineteenth-century contributions. These contributors were: from Australia, Edward J. Nanson (31), James Cockle (45), John H. Michell (19); from India, Archdeacon John H. Pratt (15); from the United States, George A. Miller (19), William Woolsey Johnson (12), Leonard E. Dickson (11), and James Joseph Sylvester (17 contributions he made to British journals while at the Johns Hopkins University from 1876 to 1883); from France, V. M. Amédée Mannheim (24), Charles Hermite (13), and Pontécoulant (9); from Belgium, Paul Mansion (29), and Hansen (10); and from Switzerland, Ludwig Schläfli (13).

[36]The *Messenger of Mathematics* was a repository for multiple foreign contributions. The average number of articles per foreign contributor to this journal was 4.1. This average for all journals except the *Messenger* was 2.5. Many of the prolific contributors above made most of their contributions to the *Messenger*. For example, Nanson and Buchheim made all their contributions to the *Messenger*, while 16 of Mannheim's contributions and 25 of Mansion's were to this journal.

[37]Roland Wagner-Döbler and Jan Berg, "Nineteenth-Century Mathematics in the Mirror of Its Literature: A Quantitative Approach," *Historia Mathematica* 23 (1996): 288-318 on p. 297. Wagner-Döbler and Berg considered only journal articles in pure mathematics while this study includes pure and applied mathematics, so this comparison of productivity can only be considered as approximate.

journals, the international presence does not seem to be growing steadily (see Table 6B). Of the six exclusively mathematical journals with consistent foreign contributions and the *Report of the British Association for the Advancement of Science*, which had a separate Mathematical and Physical Sciences Section, only three of these journals attained foreign page proportions of over 10%. Of these, the *Quarterly Journal of Pure and Applied Mathematics* achieved the highest percentage, 26.4%, from 1890 to 1900. Considered over the entire nineteenth century, foreign contributions represented from 4.8% of all pages of mathematics, for the *Oxford, Cambridge, and Dublin Messenger of Mathematics*, to 13.6%, in the *Quarterly Journal of Pure and Applied Mathematics*. Considering the totals for all journals, the proportion of foreign pages fluctuates through the century but ends at a high of over 12%. Three journals achieved their highest foreign page percentages during the 1890s, and for two journals, the *Quarterly Journal* and the *Proceedings of the LMS*, the 1890s percentage was at least 65% higher than any previous percentage. While slow but steady growth characterizes the number of foreign contributors and their contributions to British scientific journals, growth for the proportion of the journal literature in Britain occupied by foreign mathematics was erratic.

By comparing the page percentages of the *Quarterly Journal* with the Italian mathematical journal *Annali di matematica pura ed applicata*, we can place the information given above into a clearer context. Similar beginnings and goals make the *Annali* a relatively close Italian analog to the *Quarterly Journal*. As the *Quarterly Journal of Pure and Applied Mathematics* was founded in 1855 as a reincarnation

Journal		Table 6B: Foreign Contributions Considered by Page Length: 1800-1900										
		Foreign Math. Contributions/All Math. Contributions (in pages)*										
		1800-1809	**1810-1819**	**1820-1829**	**1830-1839**	**1840-1849**	**1850-1859**	**1860-1869**	**1870-1879**	**1880-1889**	**1890-1900**	**1800-1900**
BAAS	*Rep.*				25/297	11/85	4/132	0/322	27/388	7/236	78/525	**152/1985**
					8.4%	12.9%	3.0%	0.0%	7.0%	3.0%	14.9%	**7.7%**
	Tran				0/83	7/76	11/63	6/63	26/165	20/106	14/114	**84/670**
					0.0%	9.2%	17.5%	9.5%	15.8%	18.8%	12.3%	**12.5%**
Camb. & Dub. Math. J.						20/1152	112/1451					**132/2603**
						1.7%	7.7%					**5.1%**
Quart. J. Pure & Appl. Math.							160/1137	149/2309	356/2220	173/3000	703/2661	**1541/11,327**
							14.1%	6.5%	16.0%	5.8%	26.4%	**13.6%**
Proc. LMS								6/679	82/1850	64/3909	462/5419	**614/11,857**
								0.1%	4.4%	1.6%	8.5%	**5.2%**
Oxford, Camb., & Dub. Mess. Math.								43/1018	18/252			**61/1270**
								4.2%	7.1%			**4.8%**
Mess. Math.									176/1728	117/1920	204/2033	**497/5681**
									10.2%	6.1%	10.0%	**8.7%**
Proc. EMS										35/539	106/1515	**141/2054**
										6.5%	7.0%	**6.9%**
Total					**25/380**	**38/1313**	**287/2783**	**204/4391**	**685/6603**	**416/9710**	**1567/12,267**	**3222/37,447**
					6.6%	**2.9%**	**10.3%**	**4.6%**	**10.4%**	**4.3%**	**12.8%**	**8.6%**

of the *Cambridge and Dublin Mathematical Journal*, the *Annali di matematica pura ed applicata* replaced the *Annali di scienze matematiche e fisiche*, founded in 1850 by Barnaba Tortolini. However, while the *Quarterly Journal* filled the absence created by the cessation of its predecessor, the new *Annali* renovated and redirected Tortolini's existing journal. This journal takeover occurred in the midst of Italian political unification and was led by Enrico Betti, Francesco Brioschi, and Angelo Genocchi, described by Hélène Gispert as "militant mathematicians."[38] With Tortolini, they formed an editorial board representing four Italian states and strong nationalistic desires.[39] Although the reestablishment of the *Annali* involved patriotic elements foreign to the foundation of the *Quarterly Journal*, both journals shared similar goals of internationalization. Echos of the "Address to the Reader" which appeared in the *Quarterly Journal* in 1855[40] sounded three years later in the "Avviso dei compilatori" of the new *Annali*'s inaugural volume:[41]

> The rapid and continuous development of the mathematical sciences in recent times is due mainly to the ease with which the many and various researches just conducted and the new truths just discovered can be immediately extended and proliferated by many savants at the same time in various parts of Europe. Thus, nations that want to cooperate with this

[38] Hélène Gispert, "Une comparaison des journaux français et italiens dans les années 1860-1875," in *L'Europe mathématique: Histoires, Mythes, Identités*, ed. Catherine Goldstein, Jeremy Gray, and Jim Ritter (Paris: Fondation Maison des sciences de l'homme, 1996), pp. 391-407 on p. 402. "Les mathématiciens du *Risorgimento* sont des mathématiciens militants."

[39] Laura Martini, "Mathematics and Politics: Shaping the Mathematical Landscape in Post-Unification Italy," *Festschrift for Laura Toti Rigatelli*, ed. Rafaella Franci and Paolo Paglia, to appear.

[40] This address is given in the introduction to this chapter.

[41] Letters from Brioschi to Betti indicate that they had the *Quarterly Journal* in mind when they recreated the *Annali*. In particular, they used the *Quarterly Journal* as a model for the format and bibliographical articles. Francesco Brioschi to Enrico Betti, 28 April 1857, 6 May 1857, Betti Archive, Scuola Normale Superiore di Pisa. I thank Laura Martini for informing me of these letters and for sharing them with me.

> progress need journals that diffuse with speed and regularity new discoveries of their scholars, and that facilitate the means to keep abreast with the general development of science...
>
> The editors realize the gravity of the work which they will undertake... They believe (and otherwise would not have begun this publication) that Italian savants will support a journal that wants to represent the state of science among us, so that this journal can call the continuous attention of scholars of other countries and in order to cease the lament that our works are unknown outside of Italy.[42]

Acting on the complementary objectives of bringing European mathematics to Italy and presenting Italian mathematics to Europe, the editorial board of the *Annali* secured contributions from eminent mathematicians both at home and abroad. Foreign contributions represented a significant portion of the content of the first 20 years of the new *Annali*: the percentage of authors, articles, and pages of the journal which were foreign increased steadily until reaching over 60% in the 1870s (see Table 6C). However, for the rest of the nineteenth century, this presence from abroad lessened considerably, with foreign contributions and pages having less than a 20% share in the *Annali*.[43]

Disregarding fluctuations between the decades, the total foreign page percentages

[42]"Avviso dei compilatori," *Annali di matematica pura ed applicata* 1 (1858): 5. "Il rapido e continuo incremento delle Scienze Matematiche in questi ultimi tempi, è dovuto principalmente alla facilità con cui le molte e varie ricerche appena intraprese, le nuove verità appena scoperte possono subito estendersi e fecondarsi da molti geometri contemporaneamente in varie parti d'Europa. Quindi per tutte le nazioni, che vogliono cooperare a questo progresso, la necessità di periodici che diffondano con prestezza e regolarità i nuovi trovati dei loro dotti, e che agevolino il modo di seguire il generale avanzamento della Scienza... I compilatori sentono tutta la gravità dell'impressa alla quale si accingono... Essi confidano (ed altrimenti no avrebbero intrapresa questa pubblicazione) che i geometri Italiani si impegneranno perché un giornale che si propone di rappresentare lo stato della scienza tro noi, possa richiamare l'attenzione continua dei dotti degli altri paesi; e far cessare il lamento che nostri lavori non sono conosciuti fuori d'Italia."

[43]Laura Martini has suggested that this downswing in foreign contributions was possibly due to the growing strength of Italian mathematicians. While the editorial board of the *Annali* initially either had to supply quality articles themselves or obtain them from abroad, they later sustained the quality of their journal through an abundance of domestic contributions.

Table 6C:
Foreign Authors and Contributors to the *Annali di Matematica Pura ed Applicata*, 1858-1900

Years†	Foreign Authors‡		Foreign Contributions		Extent of Foreign Contributions	
	#	%*	#	%§	Pages	%
1858-1859	16	50.0%	24	25.8%	218	27.8%
1860-1869	40	55.6%	75	41.7%	1045	42.8%
1870-1879	41	67.2%	83	61.9%	1375	62.0%
1880-1889	13	27.7%	22	18.8%	414	16.6%
1890-1900	11	16.9%	17	9.2%	454	11.5%
Total, 1858-1900	**85**	**43.8%**	**221**	**33.0%**	**3503**	**29.5%**

† Here, the year limits are estimated. For example, 1870-1879 includes volume 3, series 2, whose coverage begins in October 1869.

‡ The nationalities of 22 authors were not identified. Of these, 17 wrote in Italian and have Italian surnames; 1 wrote in Italian with a French surname; 3 wrote in French; and 1 wrote in German.

* Percentages are rounded to the nearest 0.1%

§ Anonymous contributions are not accounted for in this percentage.

Foreign Authors and Contributors to the *Quarterly Journal for Pure and Applied Mathematics*, 1855-1900

Years†	Foreign Authors‡		Foreign Contributions		Extent of Foreign Contributions	
	#	%	#	%	Pages	%
1855-1859	9	16.4%	21	11.5%	160	14.1%
1860-1869	7	9.5%	19	5.5%	149	6.5%
1870-1879	11	20.0%	25	9.2%	356	16.0%
1880-1889	8	11.6%	12	5.0%	173	5.8%
1890-1900	17	27.0%	35	22.2%	703	26.4%
Total, 1855-1900	**40**	**20.7%**	**112**	**9.4%**	**1541**	**13.6%**

† Here, the year limits are estimated. For example, 1855-1859 includes volume 3, whose coverage ends in 1860.

‡ The nationalities of 11 authors were not identified. Besides the 13 signed articles of these 11 authors, four articles were signed with initials or aliases, and 23 were anonymous.

show that foreign contributions were considerably more plentiful in the *Annali* than in the *Quarterly Journal.* Although the *Quarterly Journal* enjoyed the highest decade percentage and one of the highest total percentages of foreign pages among the British scientific journals in this study, its international composition pales with that of the *Annali.* The minor role of international articles in the *Quarterly Journal* as compared with its Italian analog suggests that the internationalization of the mathematical content of British scientific journals lagged behind that of other European journals.[44]

While the British mathematical publication community's internationalization efforts, in terms of page percentages, failed to surpass those of other nations, they did result in a geographically diverse group of foreign contributors. This group contained a significant number of authors from the Americas, Asia, and Australia, while the *Annali*, for example, had only European contributors.[45] The wide geographical distribution of these contributors reveals support given to British mathematics by established centers of mathematics as well as publication opportunities taken by emerging groups of mathematicians especially in former or then-current British colonies (see Table 6D).[46] The comparatively high French mathematical presence in

---

[44]Wolfgang Eccarius' statistics about the international distribution of authors and contributions to the *Journal für die reine und angewandte Mathematik* (1826-1855) support this suggestion. Eccarius considered the first 50 volumes (1826-1855), produced during the editorship of August Leopold Crelle, and found that foreigners (that is, non-Germans) represented 30.2% of the contributors and authored 25.7% of the contributions which account for 23.9% of the journals' pages. Wolfgang Eccarius, "August Leopold Crelle als Herausgeber des Crelleschen Journals," *Journal für reine und angewandte Mathematik* 286/287 (1976): 5-25 on p. 21.

[45]This study considers mathematicians writing from anywhere outside of Britain, including the British colonies, as foreign.

[46]In this study, contributors are identified with the countries from which they wrote. For example, the contributions Sylvester made to British journals while at the Johns Hopkins University are considered to be from the United States.

Table 6D: Foreign Contributors by Region and Decade: 1800-1900

Region or Country*		Number of Contributors : Number of Contributions										
		1800-1809	1810-1819	1820-1829	1830-1839	1840-1849	1850-1859	1860-1869	1870-1879	1880-1889	1890-1900	**1800-1900**
United States								1:2	12:37	17:30	37:97	**59:166**
France		2:7	1:1	2:3	3:5	4:4	9:16	6:13	8:20	8:32	13:22	**42:123**
British Colonies	Australia							2:26	4:39	5:19	4:34	**8:118**
	Other			1:1		1:1	1:2	4:19	7:12	7:11	12:22	**25:68**
Germany					1:2	2:4	6:11	4:11	11:14	10:13	8:8	**36:63**
Belgium					1:1	1:4	2:5	2:6	1:24	1:2	1:3	**4:45**
Northern Europe						1:2	5:8	7:13	6:9	4:4	3:7	**22:43**
Italy				2:2	1:1		6:8	3:5	5:7	6:9	1:1	**14:33**
Eastern Europe	Austria			1:1	1:1				1:1		2:4	**4:7**
	Other							3:3	4:6	4:5	2:3	**12:16**
Russia						3:4	2:3	1:1	1:1	2:6	2:2	**9:17**
Switzerland					1:2		1:6	1:7			1:1	**3:16**
Far East										2:2	4:5	**5:7**
Southern Europe									1:1	2:2	1:1	**3:4**
South America							2:3					**2:3**

* Region and countries are by modern borders.
British Colonies: Australia, Canada, India, South Africa, New Zealand.
Eastern Europe: Austria, Czech Republic, Hungary, Poland, Rumania.
Far East: Japan
Northern Europe: Denmark, Netherlands, Sweden, Norway.
South America: Brazil.
Southern Europe: Portugal, Spain, Greece.

British journals up to the middle of the nineteenth century reflects the strength of French mathematics during this period. Likewise, the growth of German mathematical contributions coincides with the emergence of Germany as a mathematical power later in the nineteenth century.

Mathematical contributions from the British colonies increased considerably during the last third of the nineteenth century.[47] This late growth in these contributions suggests that, by the end of the nineteenth century, Britain's colonial mathematical outposts were only beginning to emerge as communities.[48] Over 30% of these contributions concentrated on one journal, the *Messenger of Mathematics.* Moreover, these articles represent over 35% of the total foreign contributions to the journal.[49]

The most remarkable growth in foreign mathematical contributions came from the United States. While it produced no mathematical contributions before 1868, the United States provided a substantial number of contributions during the 1870s and 1880s and an unrivaled number during the 1890s.[50] In fact, with the exception

[47]A mathematician is termed as "colonial" as long as he for resided in a British colony. For example, the contributions of Horace Lamb, a frequent contributor to the *Messenger of Mathematics*, are considered as Australian for the period from 1876 to 1885, when Lamb was Professor of Mathematics at Adelaide University.

[48]This suggestion agrees with the later, twentieth-century foundation of mathematical societies of Canada, Australia, New Zealand, and Calcutta. The trend of late nineteenth-century and early twentieth-century growth also agrees with the colonial mathematical presence in June Barrow-Green's BRITMATH database. This database, which covers British mathematics from 1860 to 1940, contains biographical data on 71 colonial mathematicians. Of these, only six held university appointments which began before 1871, 24 began their appointments from 1871 to 1900, 35 held twentieth-century appointments, and six were undetermined.

[49]Nine out of the 33 colonial contributors (27%) contributed to the *Messenger of Mathematics.* From the United States, 13 out of 59 (22%) of its contributors published in the *Messenger*; their contributions accounted for 19.3% of all U.S. contributions, and 22.5% of all foreign contributions to the *Messenger.*

[50]All but 11 of the 37 United States contributions made during the 1870s were to the *Messenger of Mathematics* or its predecessor, the *Oxford, Cambridge, and Dublin Messenger of Mathematics.* However, the *Messenger*'s United States contributions waned during the nineteenth century's last

of France and Australia, American contributors and contributions from 1890 to 1900 outnumbered those of every other foreign country for the entire century. This rapid increase followed the general trend of nineteenth-century graduate education in the United States; in 1870, there were 44 graduate students in America, while by 1900 there were as many as 5,668. [51]

Almost one-fifth of the American contributions came from just two men: Leonard Eugene Dickson and George A. Miller. In their "Profile of the American Mathematical Research Community: 1891-1906," Della Fenster and Karen Parshall found that Dickson and Miller were highly active at home as well as in Britain. For the years studied, Dickson published 67 papers and Miller published 62 in the four mathematical journals extant in the United States.[52] Moreover, Dickson and Miller were the most prolific contributors to these journals among the 62 "most active" members of the American mathematical community at that time.[53]

After earning his doctorate in 1893 from Cumberland College in Kentucky and

---

two decades: four of the 30 1880s contributions and only eight of the 97 1890s contributions were to this journal.

[51]Karen Hunger Parshall and David E. Rowe, *The Emergence of the American Mathematical Research Community: 1876-1900: J.J. Sylvester, Felix Klein, and E.H. Moore*, HMATH, vol. 8 (Providence: American Mathematical Society and London: London Mathematical Society, 1994), pp. 262-263.

[52]Della Dumbaugh Fenster and Karen Hunger Parshall, "A Profile of the American Mathematical Research Community: 1891-1906," in *The History of Modern Mathematics*, vol. 3, ed. Eberhard Knobloch and David E. Rowe (Boston: Academic Press, 1994), pp. 179-227 on p. 186. The four extant journals were the *Bulletin of the American Mathematical Society*, the *Transactions of the American Mathematical Society*, the *Annals of Mathematics*, and the *American Journal of Mathematics*.

[53]"Most active" mathematicians contributed, on average, at least one publication (to the four extant U.S. journals), talk, or year of service (to the American Mathematical Society or the American Association for the Advancement of Science) per year over the period from 1891-1906. See Fenster and Parshall, pp. 184-186. Out of the 43 American contributors to British journals, 16 were considered "most active" and six were considered "active" by Fenster and Parshall in the American mathematical community.

serving as an instructor for two years at the University of Michigan, Miller augmented his mathematical training in Leipzig and Paris. Throughout this European tour and afterward, back in America, Miller focused his energies on group theory. The sheer number of his results often outweighed their profundity, and he "literally made a career out of dissecting finite groups in virtually every way conceivable."[54] His contributions to British journals reflected these interests; in these, Miller listed primitive, transitive, and intransitive substitution groups, or all groups in general, for certain orders. Miller's numerous results sometimes found unconventional homes. The appearance of his articles, "The Substitution Groups whose Order is Four," "The Operation Groups of order $8p$, p being any prime number," "The Transitive Substitution Groups of Order $8p$, p being any prime number," and "On the Simple Isomorphisms of a Substitution-Group to itself," to the *Philosophical Magazine* formed a sharp contrast to the applied mathematics articles which usually appeared there.[55]

Dickson also contributed heavily to group theory but attained results with more depth and coherence than Miller's. With an 1896 University of Chicago PhD in hand, Dickson, like Miller, pursued postdoctoral studies in Leipzig and Paris. The research Dickson accomplished while on the faculties of the Universities of California, Texas,

[54]Fenster and Parshall, pp. 209-210.

[55]These appear in series 5 of the *Philosophical Magazine* in volume 41 (1896): 431-437, 42 (1896): 195-200, 43 (1897): 117-125, and 45 (1898): 234-242, respectively. Brock and Meadows have estimated that, "by the last quarter of the nineteenth century, eighty to ninety per cent of all [*Philosophical Magazine*] articles dealt with physics. By the beginning of the twentieth century, the *Philosophical Magazine* was recognised as being essentially a physics journal." William H. Brock and Arthur Jack Meadows, *The Lamp of Learning: Taylor & Francis and the Development of Science Publishing* (London: Taylor & Francis, 1984), p. 206.

and, ultimately, Chicago, strengthened the foundation of algebraic excellence in the United States.[56] To the *Quarterly Journal of Pure and Applied Mathematics*, Dickson contributed a series of papers which generalized group-theoretic results from Camille Jordan's *Traité des substitutions*.[57] Dickson also investigated linear groups in several of his nineteenth-century British contributions.[58] He soon codified his linear group research in the book, *Linear Groups with an Exposition of the Galois Field Theory*, which appeared in 1901 and inspired American interest in finite group theory.[59]

The mathematical training of Dickson, Miller, and the other 57 American authors published in British journals provides a characteristic example of the educational paths taken by American mathematics students during the last quarter of the nineteenth century. At least one-third of these contributors pursued mathematical studies abroad;[60] this fact illustrates the American reliance on European universities for advanced mathematics training after Sylvester left the Johns Hopkins University in 1883.[61] However, since at least 46% of these contributors received graduate mathe-

[56]Parshall and Rowe, p. 381.

[57]Leonard E. Dickson, "A Triply Infinite System of Simple Groups," "The First Hypoabelian Group Generalized," and "Simplicity of the Abelian Group on Two Pairs of Indices in the Galois Field of Order $2n$, $n > 1$," in *Quarterly Journal of Pure and Applied Mathematics* 29 (1898): 169-178; 30 (1899): 1-16; and 30 (1899): 383-384.

[58]Leonard E. Dickson, "A Class of Linear Groups including the Abelian Group," *Quarterly Journal of Pure and Applied Mathematics* 31 (1900): 60-66; "The Structure of Certain Linear Groups with Quadratic Invariants," and "Concerning the Four Known Simple Linear Groups of Order 25920, with an Introduction to the Hyper-Abelian Linear Groups," *Proceedings of the London Mathematical Society* 30 (1899): 70-98; 31 (1900): 30-68.

[59]Parshall and Rowe, p. 381.

[60]At least 19 out of 57 of these contributors received training abroad and at least six received this training in Britain. For a discussion of the foreign education of the "most active" American mathematicians, see Fenster and Parshall, pp. 202-203.

[61]For Sylvester's foundation of a research-level mathematics program at the Johns Hopkins, see Karen Hunger Parshall, "America's First School of Mathematical Research: James Joseph Sylvester at the Johns Hopkins University, 1876-1883," *Archive for History of Exact Sciences* 38 (1988): 153-196, and Parshall and Rowe, pp. 53-97.

matical training at home,[62] Europe was not the only option for advanced study.

Beyond geographical factors, the personal influence of a few British mathematicians as well as the efforts of British scientific societies prompted many foreign mathematicians to contribute. Biographical information about the foreign contributors, and references made by the authors themselves in their contributions, indicated personal factors or scientific society influences for almost half of the articles (see Table 6E).[63]

Over 6% of foreign contributions were written in response to work the authors had read in British scientific journals. For these responses, British journals represented a forum for constructive argument and criticism between foreign and domestic mathematicians. In his *Convolutions in French Mathematics, 1800-1840*, Ivor Grattan-Guinness described one of these arguments as exemplifying "the growing internationalisation of science."[64] In 1826, Siméon-Denis Poisson published "Sur l'attraction des sphéroïdes" in *Connaissance des temps.* There, he codified his previous research as well as the work of Laplace in this area.[65] James Ivory, a retired Professor from the Royal Military College, Marlow, disagreed with Poisson's treatment of an integral concerning surface harmonics. The next year, he addressed his concerns with "Some Remarks" in the *Philosophical Magazine*: "[w]ill this pass for demonstration? It is a mere assertion. It is one of those curt and imperative attempts at proof, of which

[62]At least 26 out of the 57 contributors received American graduate training (in addition, possibly to graduate training abroad); 15 of these received their training exclusively in the U.S. The training of four of the American contributors has not been determined.
[63]These factors were not disjoint. Thus, the percentages in Table 6E do not add to 100%.
[64]Ivor Grattan-Guinness, *Convolutions*, 2: 1190.
[65]*Ibid*, 2: 1192.

Table 6E: Factors for Foreign Contributions to British Journals: 1800-1900

Factor	Number	Percent*
Asked to contribute by a British mathematician.	8	1.1%
Had an article translated by a British mathematician.	13	1.8%
Contribution was a letter extract to a British mathematician.	15	2.1%
Contribution was communicated by a British mathematician.	20	2.7%
Responded to work read in a British scientific journal.	47	6.4%
Spent time in Britain.†	131	18.0%
Cited a British mathematician in contribution.	82	11.2%
Awarded medals, memberships, or grants by British scientific societies.§	262	35.9%
Undetermined.	247	33.9%

* Percentage out of the 729 contributions. Since these factors are not disjoint, the percentages do not add to 100%.

† The contributor was born in, educated in, worked in, or visited Britain. 127 of these contributions (96.9%) are from contributors who spent time in Britain *before* making their mathematical contribution.

§ This category includes contributors who received medals, memberships, or grants from British scientific societies *at any time* during their careers.

too many occur in the modern mathematics, which are none of its improvements, and which ought never to be admitted without scrupulous examination."[66] Poisson submitted a defense against Ivory's criticisms that was published in the next volume of the *Philosophical Magazine.* While he clarified some of Ivory's objections, Poisson did not definitively settle the argument. Grattan-Guinness described the debate between Poisson and Ivory as "another example of a problem in *multi*-variate analysis which surpassed the powers of the time."[67] The publication of this debate in the *Philosophical Magazine* opened an international dialogue between the two mathematicians.

While quite small, the group of British mathematicians who made international interaction a priority influenced foreign contributors in a variety of ways. Thomas Hirst's efforts in this direction illustrate the variety of forms international encouragement could take.[68] In 1850, Hirst began a lifelong relationship with international mathematics with graduate study at the University of Marburg. After earning his PhD there in 1852 with a thesis on analytic geometry entitled, "On Conjugate Diameters of the Triaxial Ellipsoid," he traveled to Göttingen, where he met Carl Friedrich Gauss. He then visited Berlin, where he began friendships with Peter Lejeune-Dirichlet and Jakob Steiner; the latter's approach to synthetic geometry particularly appealed to Hirst. This continental tour, taken so early in his life, ended in Paris

[66]James Ivory, "Some Remarks on a Memoir by M. Poisson, read to the Academy of Sciences at Paris, Nov. 20, 1826, and inserted in the *Connaissance des temps* 1829," *Philosophical Magazine*, new series, 1 (1827): 324-331 on pp. 326-327.

[67]Ivor Grattan-Guiness, *Convolutions,* 2: 1194. His emphasis.

[68]The following account of Hirst's life is based on J. Helen Gardner and Robin J. Wilson, "Thomas Archer Hirst — Mathematician Xtravagant Parts I - VI," *American Mathematical Monthly* 100 (1993): 435-441, 531-538, 619-625, 723-731, 827-834, and 907-915.

where he attended the lectures of Joseph Liouville and Gabriel Lamé.[69]

During a return visit to Paris in 1857, Hirst spent much of his time translating significant mathematical works. In particular, he translated into English the work of Louis Poinsot on the percussion of bodies, which appeared in installments from 1858 to 1859 in the *Philosophical Magazine*.[70] Hirst completed the translation "with the consent of the author and with the advantage of occasional suggestions from him."[71] In his diary, Hirst recounted a meeting with Poinsot, during which the French mathematician remarked, "[w]e cast our seed upon the waters knowing not where it may fall, but it is nevertheless pleasant after long years of labour to find that these seeds have taken root."[72] In his translator's footnote, Hirst extolled the virtues of this work; he then painted a mixed picture of the British reception of French mathematical works. Hirst asserted that "[m]athematicians at this day, too, are so well acquainted with the current mathematical literature of our continental neighbours, that for them even an announcement of the publication, in *Liouville's Journal* for September 1857, of Poinsot's most recent memoir is superfluous; for their use, an English version of this memoir is certainly not called for."[73] Hirst did not extend his positive assessment of British mathematicians to all British mathematical practitioners, however. He continued: "[n]evertheless the works of the able author are far from being so familiar

[69]For more on Hirst's work in analytic geometry, see chapter 7.
[70]Louis Poinsot, "On the Percussion of Bodies," *Philosophical Magazine*, 4^{th} ser. 15 (1858): 161-180, 263-290, 348-359; and 4^{th} ser. 18 (1859): 241-259.
[71]Thomas Archer Hirst, in Poinsot (1858): 162.
[72]Louis Poinsot, in Gardner and Wilson, p. 727.
[73]Thomas Archer Hirst, in Poinsot (1858): 162.

to Englishmen generally as they deserve to be."[74]

Hirst continued to visit the Continent and maintained relationships with several of the foreign mathematical contributors to British journals. Besides translation, he communicated foreign articles and was cited several times in foreign contributions. For example, Rudolf Sturm, Professor at the Technische Hochschule in Darmstadt, referred to Hirst's work in projective geometry in his 1876 article, "On Correlative Pencils," in the *Proceedings of the London Mathematical Society.*[75] In Sturm's words, "[t]he present paper originated from a proposition of my friend, Dr. Hirst, whose own investigations on the correlation of two planes and of two spaces are closely connected with mine."[76]

Besides individual contacts with foreign mathematicians, Hirst exercised his influence within British scientific societies. In 1865, as a member of the Council of the Royal Society of London, Hirst successfully proposed Michel Chasles for the Society's Copley Medal. This proposal was lauded by Sylvester:

> It rejoices me to hear that Chasles has been brought forward as a Candidate for the Copley Medal. As a geometer for the fecundity of his methods and clearness and originality of his conceptions he has never been surpassed. He is the father and founder of a school of geometry whose ramification extend all over the world. Such *were* his claims to receive such a distinction at the hands of the Royal Society and had they stood still on the same footing as two years back I am bound to declare that I should have experienced some difficulty in assigning the golden apple

[74] *Ibid.*

[75] Hirst made investigations in projective geometry from the 1860s to the end of his life, a period when projective geometry particularly captivated British mathematicians. See Joan L. Richards, *Mathematical Visions: The Pursuit of Geometry in Victorian England* (Boston: Academic Press, Inc., 1988), pp. 131-143.

[76] Rudolf Sturm, "On Correlative Pencils," *Proceedings of the London Mathematical Society* 7 (1876): 175-194 on p. 176.

> to the worthiest among the three living representatives of the New Geometry Poncelet, Plücker, Chasles. But by his last crowning discovery of the most marvelous instrument of geometrical research, the most original and unlooked for organon that has ever taken the world by surprise, I consider that he has surpassed himself and should have no hesitation now in awarding to him the coveted prize.[77]

Cayley also applauded Hirst's proposal of Chasles, but also wanted the honor bestowed on Julius Plücker, Professor of Physics at the University of Bonn:

> I should be very sorry to have to make even in my own mind a decision as to the relative value of the achievements of the two geometers who have each of them so greatly contributed to bring their favourite science into the position which it now occupies. As to the absolute merits of Chasles there cannot be the shadow of a doubt; and his last discovery is as you observe, a crown to his past labors. I fully and cordially agree in the arguments you bring forward as to the Medal this year being given to him - more particularly on the ground of the danger that this may be the last opportunity for doing so - and I may say, the real misfortune it would be to the Society if they should have omitted to make such a disposition of their highest scientific testimonial.[78]

In 1867, Hirst again successfully recommended Chasles for another society honor, the London Mathematical Society's first foreign membership.[79]

Henry Smith also encouraged British interaction with international mathematics. Oxford graduate and holder of the Savilian Chair of Geometry at Oxford from 1860 until his death in 1883, Smith regularly visited foreign mathematicians on the Continent and entertained those who visited England. While not in the mainstream of

[77] James Joseph Sylvester to Thomas Archer Hirst, 1 November 1865, in Karen Hunger Parshall, *James Joseph Sylvester: Life and Work in Letters* (Oxford: Clarendon Press, 1998), p. 128. The discovery Sylvester referred to is a method for solving questions entailing conic sections which Chasles presented in "Considérations sur la méthode générale exposée dans la séance du 15 février - Différence entre cette méthode et la méthode analytique - Procédés générale de démonstration," *Comptes rendus* 58 (1864): 1167-1175. Parshall, *Life and Work*, p. 128.

[78] Arthur Cayley to Thomas Archer Hirst, 31 October (no year recorded), LMS Papers, University College London. Chasles, in fact, won the Copley Medal in 1865, and Plücker won the year later.

[79] Adrian C. Rice and Robin J. Wilson, "From National to International Society: The London Mathematical Society, 1867-1900," *Historia Mathematica* 25 (1998): 185-217 on pp. 187-189.

English mathematics, his work in number theory, especially his *Report on the Theory of Numbers* was "well received by continental mathematicians."[80] Smith, like Hirst, used his position in a scientific society to encourage international participation. As President of the Mathematical and Physical Sciences Section of the BAAS, Smith invited Hermite and Felix Klein to the 1873 meeting, where Hermite spoke on the irrationality of e.[81]

Hirst's support of foreign mathematicians for society medals and Smith's use of society activities for international outreach reflected a sense within British scientific societies that medals and memberships could promote both international scientists in Britain and British societies to international scientists. In fact, the authors of over 35% of the nineteenth-century foreign mathematical contributions received a medal from, membership in, or grant to one of these societies. Thus, for a significant proportion of the foreign members of the British mathematical publication community, these society rewards either predicted future foreign contributions or rewarded authors for contributions already made.

[80]Keith Hannabuss, "Henry Smith," in *Oxford Figures: 800 Years of the Mathematical Sciences*, ed. John Fauvel, Raymond Flood, and Robin Wilson (Oxford: University Press, 2000), pp. 203-217 on p. 206. Although Smith was internationally active, one of his number theoretical results was completely overlooked by these continental mathematicians. In his "On the Orders and Genera of Quadratic Forms Containing More Than Three Indeterminates," published in the *Proceedings of the Royal Society* in 1867, Smith gave a formula expressing the number of ways an integer can be expressed as a sum of five squares. However, 15 years later, Smith noticed an announcement in the *Comptes rendus* that posed the same problem for the Grand Prix of the French Academy of Sciences. After inquiring about this oversight in a letter to Hermite, Smith learned that no one on the committee that posed the problem knew of Smith's earlier solution. The Grand Prix eventually went to both Smith and University of Königsberg student, Hermann Minkowski; Smith, however, did not live to receive the prize. That Smith's works had been missed despite the mathematician's international renown highlights the fact that mathematics in British journals at that time had not completely entered the international arena. *Ibid*, pp. 214-216.

[81]*Ibid*, p. 212. "[P]resumably his newly discovered proof of the transcendence of e would have been too technical for such a general audience." *Ibid.*

This examination of the personal factors and scientific society influences that encouraged foreign mathematical participation in British scientific journals reveals the efforts of a small but persistent group of British mathematicians committed to bringing foreign mathematicians into the British mathematical publication community. These efforts extended to a parallel requirement of the internationalization of British mathematics: contributions by British mathematicians to the international mathematical publication community.

The Other Side of the Coin: British Mathematical Contributions to International Scientific Journals

In order to gauge the presence of British mathematicians in foreign scientific journals, British contributors were located in two ways. The initial sample consisted of the British writers in all nineteenth-century volumes of an international sample of mathematical journals: *Journal für die reine und angewandte Mathematik* (commonly called Crelle's *Journal*); *Journal de mathématiques pures et appliquées* (also known by the name of its founder, Liouville); *Annali di matematica pura ed applicata*; and *Acta Mathematica.* The bibliographies for these British mathematicians, located in the *Catalogue of Scientific Papers of the Royal Society of London*, were searched for international entries. Those international mathematical journals not among the four above, which contained a considerable number of papers by the members of the initial sample, were also searched.[82] This procedure yielded a group of 56 British

[82]This study set "considerable" to mean at least 20. This limit yielded the additions of the *American Journal of Mathematics* (with 33 articles from British mathematicians from the first sample), the *Nouvelles annales de mathématiques: journal des candidats aux écoles polytechnique et normale* (with 27 articles), and the *Mathematische Annalen* (with 24 articles) to the journal sample. Because of issues of availability, the following volumes of the *Nouvelles annales de mathématiques*

mathematicians and their contributions to the international journals recorded in the *Royal Society Catalogue.*

Looking at these contributions by decade reveals that British mathematicians first began to publish their results abroad in the 1830s, and these contributions reached a significant level in the 1840s (see Table 6F). For the remainder of the nineteenth century, these contributions showed neither a pattern of decline nor a pattern of increase; rather, the number of contributions by journal shows spikes of activity amidst decades of inactivity. These jumps become clearer when the number of authors making these contributions is considered. In fact, over one-half of these foreign articles were written by just four British mathematicians: Cayley, Sylvester, and Michael and William Roberts, twins who spent their mathematical careers at Trinity College, Dublin.[83] By separating the remaining contributions from those of the top four contributors, a much more measured picture of foreign contributions emerges (see table 6G); nevertheless, several peaks still appear for the individual journals.

One peak in the articles from British mathematicians occurred in Liouville's *Journal* during the 1840s and 1850s. Ten of these contributions came from Hirst, William Thomson, and the Trinity College, Dublin mathematician, James MacCullagh, all of whom had met or studied under Liouville during this period. In her study of Liouville's *Journal* during Liouville's tenure as editor (1836-1874), Sylvina Duvina found

could not be consulted for the second-level search described above: series 1 (vol. 7 (1848), vol. 8 (1849), vol. 9 (1850), and vol. 16 (1857)), series 2 (vol. 12 (1873) and vol. 13 (1874)), series 3 (vol. 1. (1883), vol. 4 (1885), vol. 7 (1888), vol. 14 (1895)). The French journal, *Comptes rendus hebdomadaires des séances de l'Académie des Sciences*, contained 121 articles from British mathematicians from the first sample, but is not included here because of its general science format.

[83]These four mathematicians are discussed in detail below.

Table 6F: British Contributions to Foreign Journals											
Journal	British Math. Contributors : British Math. Contributions (#:#)										
	1800-1809	1810-1819	1820-1829	1830-1839	1840-1849	1850-1859	1860-1869	1870-1879	1880-1889	1890-1900	**1800-1900**
Journal für die reine und angewandte Mathematik (1826-)			0:0	2:3	1:12	9:45*	5:21	3:15	4:11	1:3	**18:110**
Journal de mathématiques pures et appliquées (1836-)				1:1	8:51	9:20	1:1	1:2	1:1	0:0	**15:76**
Mathematische Annalen (1868-)							1:1	1:13	2:10	7:12	**9:36**
Nouvelles annales de mathématiques (1842-)					1:1	7:21	8:13	2:2	1:1	5:9	**19:47**
Annali di matematica pura ed applicata (1858-)						4:7	8:26	5:13	1:3	1:1	**10:50**
American Journal of Mathematics (1878-)								4:9	11:47	10:21	**19:77**
Acta Mathematica (1877-)								0:0	1:1	2:2	**3:3**
Total for all journals above†			**0:0**	**3:4**	**8:64**	**18:93**	**16:62**	**11:54**	**15:74**	**18:48**	**56:399**

* William Fishburn Donkin and William Spottiswoode co-authored "Two Letters of Geometrical Correspondence between Mr. Donkin and Spottiswoode," *Journal für die reine und angewandte Mathematik* 7 (1854): pp. 225-232.

Table 6G: British Contributions to Foreign Journals excepting those of Top Four Contributors

Journal	British Math. Contributors : British Math. Contributions (#:#)										
	1800-1809	**1810-1819**	**1820-1829**	**1830-1839**	**1840-1849**	**1850-1859**	**1860-1869**	**1870-1879**	**1880-1889**	**1890-1900**	**1800-1900**
Journal für die reine und angewandte Mathematik (1826-)			0:0	2:3	0:0	8:15*	3:4	2:3	2:2	0:0	**15:27**
Journal de mathématiques pures et appliquées (1836-)				1:1	5:10	6:8	0:0	1:2	1:1	0:0	**12:22**
Mathematische Annalen (1868-)							0:0	1:1	1:1	6:12	**8:14**
Nouvelles annales de mathématiques (1842-)					0:0	4:8	6:10	1:1	1:1	4:7	**15:27**
Annali di matematica pura ed applicata (1858-)						1:2	5:9	2:4	1:3	0:0	**6:18**
American Journal of Mathematics (1878-)								3:4	8:22	9:17	**17:43**
Acta Mathematica (1877-)								0:0	1:1	2:2	**3:3**
Total for all journals above[†]			**0:0**	**3:4**	**5:10**	**14:33**	**12:23**	**8:15**	**13:31**	**16:38**	**52:154**

* William Fishburn Donkin and William Spottiswoode co-authored "Two Letters of Geometrical Correspondence between Mr. Donkin and Spottiswoode," *Journal für die reine und angewandte Mathematik* 7 (1854): pp. 225-232.

a similar peak in all foreign contributions to the journal. She found 1840 to 1850 to be the years of the most prolific and notable foreign articles, and she identified a sharp decline in these contributions during the last decade of Liouville's editorship.[84] Despite the low participation by British mathematicians in the *Journal* after 1860, Britain ranked second only to Germany in foreign contributions in Duvina's study.[85]

Another peak in British mathematical articles occurred during the 1850s in Crelle's *Journal.* These contributions marked an international début for most of its authors. Only one of the eight contributors to the *Journal* during this period, William Thomson, had made his first foreign contribution before 1850, and six of these mathematicians published their first foreign article in Crelle's *Journal.* Furthermore, the international publishing careers of four of these authors only lasted through this decade. Thus, while the majority of these authors began making international publications in Crelle's *Journal*, their use of this venue was short-lived.[86]

A more lasting venue for nineteenth-century British mathematics opened in 1878 with the foundation of the *American Journal of Mathematics.* Its founder, Sylvester, actively enlisted his friends back home to support the journal. He asked Cayley to "send us any trifle at your disposal as a page *Iambi*, for our first number. The more the better."[87] Cayley, in return, provided four articles, which while short were

---

[84]Sylvina Duvina, "Le *Journal de Mathématiques pures et appliquées* sous la férule de J. Liouville (1836-1874)," *Sciences et techniques en perspective* 28 (1994): 179-217 on p. 190.

[85]*Ibid.*, p. 187. Twenty-six Germans authored 106 articles (8% of all articles) in the *Journal*, 15 British authored 75 articles (6%), six Russians authored 24 (2%), and five Italians authored ten (1%).

[86]Arthur Thacker's only foreign article and George Green's three foreign contributions were made to Crelle's *Journal* during the 1850s. Charles Graves and William Donkin made two foreign contributions each between 1850 and 1854.

[87]James Joseph Sylvester to Arthur Cayley, 24 Nov. 1877, in Tony Crilly, *Arthur Cayley, Mathe-*

hardly trifling.[88] In the first of his *Desiderata and Suggestions*, Cayley stated that "the general problem of finding all the groups of a given order n, is really identical with the apparently less general problem of finding all the groups of the same order n, which can be formed with the substitutions upon n letters;"[89] this identification of all groups with substitution groups later became known as Cayley's Theorem.[90] Sylvester did not limit his recruitment tactics to Cayley. While on summer vacation from Hopkins, Sylvester visited Paris and "secured the promise of a valuable paper from Hermite for our Journal." Additionally, "Lipschitz the Professor of Mathematics at Bonn has also engaged to send me one — and Clifford has already committed to me a very valuable memoir... and promises several more."[91] Clifford and six other British mathematicians would make their only foreign contributions to the *American Journal*. Furthermore, all but two of the 17 British contributors[92] began publishing abroad on or after the *American Journal*'s foundation, and 11 of this group made their first international contributions to the journal.[93]

matician Laureate of the Victorian Age, preprint, chapter 14, p. 6.

[88]Arthur Cayley, "Desiderata and Suggestions," "No. 1 The Theory of Groups," "No. 2 The Theory of Groups, Graphical Representation," "No. 3 The Newton-Fourier Imaginary Problem," and "No. 4 Mechanical Construction of Conformable Figures," *American Journal of Mathematics*, 1 (1878): 50-52; 174-176; and 2(1879): 97, 186.

[89]Cayley, "Desiderata and Suggestions," p. 52.

[90]Sylvester also printed Cayley's work in the intra-university publication, the *Johns Hopkins University Circular*. Sylvester wrote to Cayley that "I shall try and cull out of your letters some additional matter for the J[ohns] H[opkins] Circular. I am glad (and so is [Daniel Coit] Gilman [first President of Hopkins]) that you approve of the development which it has undergone." James Joseph Sylvester to Arthur Cayley, 16 March 1883, in Parshall *Life and Work*, p. 221.

[91]James Joseph Sylvester to Daniel Coit Gilman, 7 September 1878, in Parshall, *Life and Work*, p. 191.

[92]Here, the top four contributors are separate from this analysis.

[93]This new group of international contributors also substantially increased British articles to the *Mathematische Annalen* during the 1890s. Eight of these papers were written by four of the British contributors to the *American Journal*.

Some of the British mathematical contributions to foreign journals were duplicates of work which had appeared in other periodicals. At least 50 of the foreign contributions written by the British mathematicians in this study's sample and recorded in the *Royal Society Catalogue* were also published in another foreign or domestic journal.[94] Over half of these duplicate contributions were made by the internationally active Hirst, Cayley, and Sylvester. In 1864, soon after becoming a foreign correspondent to the *Académie des Sciences*, Sylvester communicated through Joseph Bertrand the first proof "a rule given without demonstration by Newton...for finding an inferior limit of the number of imaginary roots of an equation."[95] He had already read his results before the Royal Society, and he later printed accounts of it in the *Philosophical Transactions*, the *Proceedings of the London Mathematical Society*, and Abbé Moigno's *Les Mondes*.[96] "In so doing, he was, in a sense, maximizing the publicity

[94]These contributions are not limited to those in the eight journals from which the study obtained the sample of British mathematicians. Besides the eight initial journals, these articles were printed in *Les Mondes, Revue hebdomadaire des sciences et de leurs applications aux arts et à l'industrie* (Paris), *Société philomatique de Paris, Bulletin des sciences* (Paris), *La revue scientifique de la France et de l'étranger* (Paris), *Annali di scienze matematiche e fisiche* (Rome), *R. Accademia dei Lincei, Memorie* (Rome), *Giornale di matematiche* (Naples), *Deutsche chemische Gesellschaft* (Berlin), *Annalen der Physik und Chemie* (Leipzig), *Mathésis* (Gand), *Van Nostrand's Engineering Magazine* (New York), *Transactions of the Royal Society of New South Wales* (Sydney), and *Transactions of the Victoria Royal Society* (Melbourne). This list indicates the range of foreign publications to which British mathematicians contributed.

[95]James Joseph Sylvester, "Sur une extension de la théorie des équations algébriques," *Comptes rendus* 58 (1864): 689-691 on p. 689; also in *The Collected Mathematical Papers of James Joseph Sylvester*, ed. Henry Frederick Baker, 4 vols., (Cambridge: University Press, 1908; reprint ed., New York: Chelsea Publishing Co., 1973), 2: 361-362 on p. 361. "Quelques recherches que j'ai faites tout récemment sur la régle donnée sans démonstration par Newton... pour trouver une limite inférieure au nombre de racines imaginaires d'une équation."

[96]James Joseph Sylvester "Algebraical Researches, Containing a Disquisition on Newton's Rule for the Discovery of Imaginary Roots, and an Allied Rule Applicable to a Particular Class of Equations, together with a Complete Invariantive Determination of the Character of the Roots of the General Equations of the Fifth Degree, &c.," *Philosophical Transactions of the Royal Society of London* 154 (1864): 579-666; also in *Collected Works* 2: 376-479; "On an Elementary Proof and Generalization of Sir Isaac Newton's Hitherto Undemonstrated Rule for the Discovery of Imaginary Roots," *Proceedings of the London Mathematical Society* 1 (1865-66): 1-16; also in *Collected Works*

for the new result; he gave it to the most important scientific bodies in both his native England and in France."[97]

Mathematicians at Trinity College, Dublin also published articles in England and the Continent as well as in Ireland.[98] Scientific societies in Ireland, such as the Dublin Society, the Royal Geological Society, and the Royal Irish Academy, often gave license for their members to publish their work in England or on the Continent so that their results would be received by a larger audience.[99] TCD Fellow, Charles Graves, for example, published his "Elementary Geometrical Proof of Joachimstal's Theorem" in both Crelle's *Journal* and the *Nouvelles annales de mathématiques* in addition to the *Proceedings of the Royal Irish Academy.*[100]

While the number of contributors and contributions reveals where and when British mathematicians published abroad, the number of pages these articles occupied, weighed against the total number of pages in each journal, measures the extent of the British mathematical presence in foreign journals (See Table 6H). For every decade from the 1840s to the 1890s, at least one foreign journal in this study's sample contained more than 7% of pages written by British mathematicians. Consistent with its initially heavy international presence, the *Annali* surpassed this British percentage

2: 498-516; and "Observations sur un article de M. Poulain," *Les Mondes* 11 (1866): 435-437; also in *Collected Works* 2: 514-516.

[97]Karen Hunger Parshall and Eugene Seneta, "Building an International Reputation: The Case of J.J. Sylvester (1814-1897)," *American Mathematical Monthly* 104 (1997): 210-222 on p. 217.

[98]Charles Graves, William Roberts, and William MacCullagh, all at Trinity, made at least seven duplicate publications in this study's sample

[99]Patrick S. Cross, "The Organization of Science in Dublin from 1785 to 1835: The Men and Their Institutions," (unpublished PhD diss., University of Oklahoma, 1996), p. 142

[100]Charles Graves, "Elementary Geometrical Proof of Joachimstal's Theorem," *Proceedings of the Royal Irish Academy* 5 (1853): 70-71, *Journal für die reine und angewandte Mathematik* 42 (1851): 279, and *Nouvelles annales de mathématiques* 11 (1852): 322-323.

Table 6H: British Contributions to Foreign Journals Considered in Page Length

Journal	British Math. Contributions/All Math. Contributions (in pages)*										
	1800-1809	**1810-1819**	**1820-1829**	**1830-1839**	**1840-1849**	**1850-1859**	**1860-1869**	**1870-1879**	**1880-1889**	**1890-1900**	**1800-1900**
Journal für die reine und angewandte Mathematik			0/ 1,603	6/ 5,890	107/ 7,083	450/ 6,815	157/ 5,362	122/ 6,053	85/ 6,491	30/ 6,000	**957/ 45,297**
			0.0%	0.1%	1.5%	6.6%	2.9%	2.0%	1.3%	0.5%	**2.1%**
Journal de mathématiques pures et appliquées				2/ 2,089	406/ 4,825	185/ 4,626	6/ 4,422	46/ 4,252	12/ 4,393	0/ 5,004	**657/ 29,611**
				0.1%	8.4%	4.0%	0.1%	1.1%	0.3%	0.0%	**2.2%**
Mathematische Annalen							2/ 634	70/ 8,393	58/ 11,137	174/ 11,675	**304/ 31,839**
							0.3%	0.8%	0.5%	1.5%	**1.0%**
Nouvelles annales de mathématiques (1842-)					0/ 3,546	48/ 3,709	72/ 5,328	64/ 4,500	2/ 4,592	23/ 5,664	**209/ 27,339**
					0.0%	1.3%	1.4%	1.4%	0.0%	0.4%	**0.8%**
Annali di matematica pura ed applicata						73/ 784	204/ 2,440	168/ 2,216	27/ 2,496	22/ 3,931	**493/ 11,867**
						9.3%	8.4%	7.6%	1.1%	0.6%	**4.2%**
American Journal of Mathematics								44/ 796	896/ 3,476	774/ 4,253	**1,714/ 8,521**
								5.5%	25.8%	18.2%	**20.1%**
Acta Mathematica									14/ 4,836	165/ 4,388	**179/ 9,224**
									0.3%	3.8%	**2.0%**

* Percentages rounded to nearest 0.1%

for its first 20 years. Considering the entire nineteenth-century runs of the journals, the *American Journal of Mathematics* showed the heaviest British influence; British mathematicians wrote over 20% of the journal's pages. However, even with the multiple contributions of Cayley, Sylvester, and the Roberts brothers, the percentage of British mathematical pages in most of the journals in this sample was less than 3%. Thus, while British mathematics occupied a substantial place in initial volumes of the *Annali* and a prominent position in the *American Journal*, its place in other foreign journals was much less pronounced.

Most members of the British mathematical publication community did *not* publish articles abroad; thus, a profile of the authors who did make foreign contributions can provide insight into the motivations of this exceptional group. The alumni records of Cambridge, Oxford, and Trinity College, Dublin, as well as the *Dictionary of National Biography* and Poggendorff's *Biographical Dictionary*, provide information about the education, employment, awards, and society participation of the 56 British mathematical contributors to foreign journals (See Tables 6I and 6J, a-c).[101] Of the 47 contributors for whom educational information was found,[102] all received either undergraduate or graduate training.[103] Not surprisingly, most of the mathematicians

[101] John Venn, *Alumni Cantabrigienses; A Biographical List of All Known Students, Graduates and Holders of Office at the University of Cambridge* (Cambridge: University Press, 1922-54); Joseph Foster, *Alumni Oxonienses: The Members of the University of Oxford, 1715-1886: Their Parentage, Birthplace, and Year of Birth, with a Record of Their Degrees* (Oxford and London: Parker and Co., 1887-1888); George Dames Burtchaeli, Thomas Ulick Sadleir, ed., *Alumni Dublinenses* (Dublin: Alex. Thom & Co., Ltd., 1935); *J.C. Poggendorff's Biographisch-Literarisches Handwörterbuch zur Geschichte der Exacten Wissenschaften* (Leipzig; Johann Ambrosius Barth, 1863-1926); and Sir Leslie Stephen and Sir Sidney Lee, ed., *The Dictionary of National Biography*, (London: Oxford University Press, 1885-1901).

[102] No educational information has been found for John C. Malet.

[103] George Boole's first degree was an LLD, which he received three years *after* after becoming

pursued degrees at Cambridge. A substantial number of these Cambridge students earned the University's highest mathematical honors: nine were Senior or Second Wranglers, and ten scored first or second in the Smith Prize Examination.[104] After

Table 6I: British Mathematical Contributors to Foreign Journals

Adams, J. C.	Hammond, J.
Anglin, A. H.	Hind, J.
Baker, H. F.	Hirst, T. A.
Ball, R. S.	Ivory, J.
Bassett, A. B.	Jellett, J. H.
Bickmore, C. E.	Jenkins, M.
Blater, J.	Kempe, A. B.
Boole, G.	Larmor, J.
Booth, J.	Love, A. E. H.
Brooke, C.	MacCullagh, J.
Bryan, G. H.	MacMahon, P. A.
Casey, J.	Malet, J. C.
Cayley, A.	Miller, W. H.
Chree, C.	Muir, T.
Clifford, W. K.	Pearson, K.
Cockle, J.	Richmond, H. W.
Crofton, M. W.	Roberts, M.
Curtis, A. H.	Roberts, S.
Darwin, G. H.	Roberts, W.
Donkin, W. F.	Russell, B. A. W.
Ellis, R. L.	Salmon, G.
Forsyth, A. R.	Smith, H. J. S.
Genese, R. W.	Spottiswoode, W.
Gilbert, R.	Sylvester, J. J.
Graves, C.	Thacker, A.
Green, G.	Thomson, W.
Greenhill, A. G.	Walton, W.
Griffiths, J.	Wilkinson, T. T.

Cambridge, the mathematicians in this study's sample turned most often not to an-

Professor of Mathematics at Queen's College, Cork. Thomas Archer Hirst's most advanced formal training had been at the Halifax Mechanics Institute before he followed his friend John Tyndall to the University of Marburg for graduate study. Gardner and Wilson, p. 439.

[104]For more details about these honors, and mathematics in Cambridge, see chapter 4.

Table 6J: British Mathematical Contributors to Foreign Journals

a. Education

	Cambridge	Oxford	Trinity College, Dublin	Other British Institutions§	Foreign Institutions†
BA	28	4	11	4	0
Graduate*	24	7	9	4	3
Bar	7				

* MA, MB, LLD, or DCL. Honorary Degrees were not counted.
§ Queen's University, Ireland; University of Aberdeen; St. Andrews University; University of Edinburgh; University of London; University of Glasgow; Royal Academy, Woolwich.
†University of Marburg; University of Berlin.

b. Medals, Memberships, and Positions

Senior or Second Wrangler (Cambridge)	9
First or Second Smith's Prizeman (Cambridge)	10
Fellow, Royal Society of London	32
Royal Society Medals*	20
Officer, London Mathematical Society	11‡
London Mathematical Society Medals§	8
Officer, British Assn. For the Adv. Of Science	9‡
Membership in Foreign Scientific Society†	23
Knighthood	8

* Foreign Scientific Societies in Berlin, Brussels, Göttingen, Hungary, Leyden, Milan, Paris, Rome, Uppsala, St. Petersburg, United States
§ Copley, Gold, and Royal.
† DeMorgan and Sylvester
‡ Men who held more than one office were counted only once.

c. Employers#

Institution	Number
Cambridge	20
University College, London	4
Oxford	4
Trinity College, Dublin	10
Other Irish Universities§	9
British Secondary School Education*	8
British Military Colleges†	6
British Technical Schools‡	2
Other British Universities and Colleges¶	10
Astronomer Royal, Ireland	1
Academic Total	**66**
Ministry	3
Medicine	1
Law	6
Military	1
Non-Academic Total	**11**

Multiple positions at one institution (for example, fellow then professor at Cambridge) were counted only once.

* University College School, Sydney Sussex School, Dundee Principle School, Glasgow High School, Queenwood College, Kingstown School, Irish Education Department.

§ Queen's University, Ireland, Catholic University, Dublin University, Queen's College, Galway, Queen's University, Ireland, Queen's College, Cork.

† Royal Naval College, Greenwich, Royal Military Academy, Marlow, Royal Military Academy, Woolwich.

‡ Imperial College of Science and Tech. Indian Civil Engineering College, Civil Service Examinations.

¶ University of Glasgow, St. Andrews University, University of London, University College, Liverpool, Bristol College, Liverpool College Institution, University of North Wales.

other English institution but to Trinity College, Dublin.[105] Trinity alumni began publishing abroad in 1839 with James MacCullagh's article, "Réclamation de priorité relativement à certaines formules pour calculer l'intensité de la lumière" to the *Comptes rendus* of the Paris Academy of Sciences.[106] While he would publish four more articles in foreign journals, including one in Liouville's *Journal*,[107] MacCullagh contributed most of his articles to the *Transactions of the Royal Irish Academy*. "This was a matter of principle with him, an expression of his patriotism, to support Irish institutions, to encourage his colleagues to do the same and to take pride in them."[108] Despite MacCullagh's encouragement to publish in Ireland, five students who received their degrees during his tenure contributed to foreign journals. By the 1840s, mathematicians from Trinity College, Dublin were regular participants in the international mathematical arena.

The five Trinity College alumni, Charles Graves, John Jellett, Michael and William Roberts, and George Salmon, who graduated under MacCullagh, later all obtained fellowships at their *alma mater*.[109] As was the case for the general group of domestic contributors discussed in chapter 5, fellowships represented the most common career for all of the mathematicians in this sample.[110] If not occupying a fellowship, most

---

[105]For more details about mathematics at Trinity College, Dublin, see chapter 5.

[106]James MacCullagh, "Réclamation de priorité relativement à certaines formules pour calculer l'intensité de la lumière," *Comptes rendus* 8 (1839): 961-971.

[107]Jesper Lützen, *Joseph Liouville 1809-1882: Master of Pure and Applied Mathematics* (New York: Springer-Verlag, 1990), p. 134

[108]T.D. Spearman, "James MacCullagh," in *Science in Ireland 1800-1930: Tradition and Reform*, ed. John R. Nudds *et. al.* (Dublin: Trinity College Dublin, 1988), pp. 83-97 on p. 53

[109]In fact, of all mathematical students during MacCullagh's tenure, 20 became fellows. Spearman, p. 42.

[110]At least 21 of the mathematicians in this sample received university fellowships.

of these mathematician were likely to hold some type of employment at a university, college, or school. Law represented the most common non-academic vocation for the men in this sample. As noted in chapter 5, both Sylvester and Cayley eventually studied law after finishing their studies at Cambridge.[111] Relative to Cayley's decision to become a lawyer, Tony Crilly noted that "Law was practically the only alternative to a college position... A man who obtained a position in the Law would be able to conduct research run in parallel with the occasional legal business over which he would have total control."[112]

Outside of their occupations, the mathematicians in this sample played active roles in British scientific societies. Over half were fellows of the Royal Society of London, and at least six of these held offices in the Society.[113] This group also included nine presidents of the London Mathematical Society,[114] and five presidents of the British Association for the Advancement of Science.[115] Several of these mathematicians were also active in foreign societies, and those who did hold foreign memberships tended to hold several different ones. Sylvester, an extreme example, was a corresponding member of the Institut de France, the Société philomathique de Paris, the Imperial Academy of Science of St. Petersburg, the Royal Academy of Science of Berlin, the

[111]While studying law, Sylvester worked as an actuary in the Equity and Law Life Assurance Society, and he probably undertook legal studies in order to advance his actuarial career. Parshall, *Life and Work*, p. 2.

[112]Crilly, chapter 6, p. 3.

[113]Three in this group, John Couch Adams, William Spottiswoode, and William Thomson, served as presidents of the Royal Society.

[114]These LMS presidents were Cayley, James Cockle, Andrew Forsyth, Hirst, Percy MacMahon, Samuel Roberts, Henry Smith, Spottiswoode, and Sylvester.

[115]These BAAS presidents were Cayley, George Howard Darwin, Andrew Forsyth, Percy MacMahon, and Spottiswoode.

Instituto Lombardo of Milan, and a foreign associate of the American Association for the Advancement of Science. Thus, these mathematicians played active roles in scientific societies, especially the Royal Society and the London Mathematical Society, and they included among their ranks some of the most influential members of these organizations.

While the 56 British mathematicians profiled above made contributions to foreign journals throughout the nineteenth century, they were, as noted, dominated by Cayley, Sylvester, and the Roberts brothers.[116] These four mathematicians established extended relationships with foreign editors and savants and considered foreign exposure of their work as critical to their mathematical careers.

The 967 articles found in his *Collected Mathematical Papers* attest to the unbounded energy Cayley devoted to journal publications; the fact that 220 of these articles were published in foreign journals confirms that he was not satisfied to limit this energy to Britain alone. As a 23-year-old Minor Fellow at Trinity College, Cambridge, Cayley made his first foreign contribution to Liouville's *Journal.*[117] A few months later, when his fellow Cambridge graduate, William Thomson, made a trip to Paris, Cayley was able to provide him with introductions to continental mathematicians including, most importantly, Liouville.[118] Thomson would become the French editor's "closest British friend and most talented foreign protégé."[119] Upon learning

[116]250 out of the 399 British contributions were made by these four mathematicians.
[117]Arthur Cayley, "Mémoire sur les courbes du troisième ordre," *Journal de mathématiques pures et appliquées* 9 (1844): 285-293.
[118]Crilly, chapter 5, p. 8.
[119]Lützen, p. 134.

about Cayley's decision in 1846 to leave Cambridge for a career in law, Liouville anxiously wrote to Thomson that

> I have been told that he was giving up mathematics and that he wanted to become a lawyer. This would be a real misfortune for science. Nature has done everything for Mr. Cayley who must help it by work and patience. By endeavouring to put a little more order and above all a little more clarity in his writings, he would soon be placed among the most distinguished analysts of the times. England owes it to itself and Mr. Cayley owes it to his country and to all those who love geometry not to allow such a clear obvious vocation as that to be lost.[120]

Liouville need not have worried. In the absence of a system in Britain promoting professional mathematicians, Cayley considered his new career as an avenue, rather than a roadblock, to further mathematical research.

During his first year as a law student, Cayley established himself as a regular contributor to Crelle's *Journal.* In his first contribution to the *Journal,* made a year earlier in 1845, he announced work on a new class of algebraic functions he called hyperdeterminants (a special class of what would be named "invariants" seven years later by Sylvester) and directed the reader to an upcoming article in the *Cambridge Mathematical Journal* for an explanation of "the first principles of this theory."[121] After clarifying his ideas in the promised article and in a subsequent work in the newly formed *Cambridge and Dublin Mathematical Journal,* Cayley diffused these ideas to a more international audience by producing a French translation of these two articles as his second contribution to Crelle's *Journal.*[122] In it, Cayley introduced a method for

[120] Joseph Liouville to William Thomson, 29 July 1847, quoted in Crilly, chapter 6, p. 8.

[121] Arthur Cayley "Note sur deux formules données par M.M. Eisenstein et Hesse," *Journal für die reine und angewandte Mathematik,* 29 (1845): 54-57 on p. 55. "Je me propose de poser les premiers fondemens de cette théorie dans un mémoire qui va paraître dans le prochain No. du 'Cambridge Mathematical Journal'."

[122] Arthur Cayley, "On the Theory of Linear Transformation," *Cambridge Mathematical Journal*

calculating hyperdeterminants which involved the so-called hyperdeterminant derivative. While Cayley himself did not pursue this method, it was valued years later by German mathematicians for its theoretical significance.[123]

These articles to Crelle's *Journal* marked the beginning of Cayley's domination of British contributions of German mathematical journals. His work commanded over 70% of all British contributions to Crelle's *Journal* and over 90% of those to the *Mathematische Annalen* for the journal's first two decades (See Table 6K). While not as dominant, Cayley's foreign contributions to mathematical journals in France, Italy, and the United States were considerable throughout his mathematical life.[124] Cayley's international contributions received an audience. For example, his work in invariant theory influenced the notation, methods, or outlook of Charles Hermite in France, Francesco Brioschi and Francesco Fàa di Bruno in Italy, and Siegfried Aronhold, a student of Otto Hesse, in Prussia.[125] Moreover, in his landmark *Traité des substitutions et des equations algébriques* of 1870, Camille Jordan acknowledged Cayley's contributions to group theory.[126] While the large number of works he presented

4 (1845): 193-209; "On Linear Transformations," *Cambridge and Dublin Mathematical Journal* 1 (1846): 104-122; and "Mémoire sur les hyperdéterminants" *Journal für die reine und angewandte Mathematik* 30 (1846): 1-37.

[123]Crilly, chapter 5, p. 11. In 1854, Cayley's "Nouvelles recherches sur les covariants" appeared in Crelle's *Journal* and presented the method which would direct his study of invariant theory. While Sylvester considered this method "an engine that mightiest instrument of research ever yet invented by the mind of man — a Partial Differential Equation, to define and generate invariantive forms," Crilly stated that "[i]n retrospect it was the wrong road taken since the hyperdeterminant derivative held more theoretical potential and was the basis for the future German symbolic calculus developed in the 1860s." (chapter 7, pp. 19-22). Arthur Cayley "Nouvelles recherches sur les covariants," *Journal für die reine und angewandte Mathematik* 47 (1854): 109-124.

[124]Cayley made 32 contributions to the *Comptes rendus*, 19 to Liouville's *Journal*, 11 to the *Annali*, 26 to the *American Journal of Mathematics*, and 12 to the *Johns Hopkins University Circular.*

[125]Crilly, chapter 8, pp. 6-7

[126]*Ibid.*, chapter 14, p. 8

Table 6K: Cayley's Contributions to Foreign Journals

Years	Contributions to				Contributions to all Journals*		Extent of Foreign Contributions	
	Journal für die reine und angewandte Mathematik		*Mathematische Annalen*					
	#	% of all British§	#	% of all British	#	% of all British†	Pages	% of all British
1840-1849	12	100%			28	43.8%	232	45.2%
1850-1859	30	66.7%			40	43.0%	245	32.4%
1860-1869	15	71.4%	1	100%	22	35.5%	97	22.0%
1870-1879	14	93.3%	13	92.9%	28	51.9%	180	35.0%
1880-1889	7	63.6%	9	90%	33	44.6%	408	37.8%
1890-1900	3	100%	1	8.3%	4	8.9%	116	10.0%
Total	**81**	**73.6%**	**24**	**66.7%**	**155**	**38.8%**	**1278**	**23.8%**

* I.e., all journals in the sample (*Journal für die reine und angewandte Mathematik, Journal de mathématiques pures et appliquées, Mathematische Annalen, Nouvelles annales de mathématiques, Annali di matematica pura ed applicata. American Journal of Mathematics,* and *Acta Mathematica)*

§ Percentages rounded to nearest 0.1%

to foreign journals indicated Cayley's goal to enter the international mathematical arena, the reception that his innovations was given abroad showed that he was solidly within its ranks.

Cayley's long-time friend, Sylvester, also considered international ties and publications as central components of his mathematical life, and only Cayley outnumbered Sylvester in his output of articles to foreign journals.[127] Although he was seven years older than Cayley, Sylvester's first foreign contribution came eight years after that of his "mathematical alter ego."[128] However, even before this article's publication, Sylvester was well on his way to making his name known abroad. He could already count himself as a corresponding member of the *Société philomatique de Paris* and, through his correspondent Irenée-Jules Bienaymé, Sylvester had sent copies of his invariant-theoretical research to Joseph Bertrand, Michel Chasles, Eugène Catalan, Augustin-Louis Cauchy, Charles Hermite, Joseph Serret, and Olry Terquem.[129]

Some of Sylvester's motivation for promoting his work abroad involved concerns about priority. One instance that illustrates the importance Sylvester placed on the proper citation of his work appeared within an article to the *Cambridge and Dublin Mathematical Journal.* In it, Sylvester lodged the following complaint:

> I take this opportunity of entering my simple protest against the appropriation of my method of finding the resultant of any set of three equations of degrees equal or differing only by a unit, one from those of the other

[127]Sylvester made 93 foreign contributions, not counting those he made while at the Johns Hopkins University from 1876 to 1883.

[128]Parshall and Seneta, p. 210. This first contribution was "Sur une propriété nouvelle de l'équation qui sert a déterminer les inégalités séculaires des planètes," *Nouvelles annales de mathématiques* 11 (1852): 434-440.

[129]Parshall and Seneta, p. 213.

> two, by Dr Hesse, so far as regards quadratic functions, without acknowledgement... Still more unjustifiable is the subsequent use of the *dialytic* principle, by the same author, equally without acknowledgement, and in cases where there is no peculiarity of form of procedure to give even a plausible ground for evading such acknowledgment.[130]

Sylvester had published the results in the *Philosophical Magazine* four years earlier, and they had been overlooked by Hesse.[131] Sylvester's agitation stemmed from the two possible reasons for Hesse's lack of citation: he had either missed the article while reading the *Philosophical Magazine* or he did not read the journal, which would be "all the worse for those British mathematicians trying conscientiously to make their work known to the broader community of mathematicians through that means."[132] While this dispute was soon cleared up amicably,[133] the priority of publications would remain important to Sylvester throughout his career.

Sylvester carried the experience of working within the international arena with him to Baltimore when he became the first Professor of Mathematics at the Johns Hopkins University. Although his friend, Hermite, had questioned Sylvester's move to the United States, asking "[i]s there really a mathematical future for the New World,"[134] Sylvester's students soon began to produce research that impressed European mathematicians. For example, in 1881, Fabian Franklin printed a surprising

[130]James Joseph Sylvester, "Sketch of a Memoir on Elimination, Transformation, and Canonical Forms," *Cambridge and Dublin Mathematical Journal* 6 (1851): 192-193; also in *Collected Mathematical Papers*, 1: 189.

[131]James Joseph Sylvester, "On a Linear Method of Eliminating between Double, *Treble*, and Other Systems of Algebraic Equations," *Philosophical Magazine* 18 (1841): 425-435; also in *Collected Mathematical Papers*, 1: 75-85.

[132]Parshall and Seneta, pp. 215-216.

[133]Just two years later, in 1854. Sylvester picked Hesse as a reference for his bid for the professorship of mathematics at the Royal Military Academy at Woolwich. *Ibid.*, p. 216.

[134]Charles Hermite to J.J. Sylvester, 29 April 1881, in Parshall and Rowe, p. 123.

result in the *Comptes rendus* that he had hit upon while attending Sylvester's number theory course.[135] Franklin's article proved Legendre's formulation of Euler's pentagonal number theorem, and "the technique he used in it raised eyebrows in France."[136] After receiving Franklin's result, Hermite rethought his earlier estimate of American mathematics, asking Sylvester to "[p]lease tell Mr. Franklin that his talent is appreciated, as it deserves to be, by the mathematicians of the old world."[137]

Besides encouraging his students to publish their work abroad, Sylvester made 50 continental contributions during his tenure at Hopkins. In a letter to Cayley, he revealed that his mathematical competitors lived on both sides of the Atlantic: "I sent to the Comptes Rendus two or three days ago my proof of the wonderful theorem (discovered by observation) [on] partitions of n into odd numbers and its partitions into unequal numbers. Franklin, Mrs. Franklin [the former Christine Ladd], Story, Hathaway, Ely, and Durfee [all at Hopkins] were all at work trying to find the proof — but I was fortunately beforehand with the theory and the only one in at the death."[138]

Long before returning to England in 1883, Sylvester's international reputation was secure. He had established friendships, collaborations, correspondents in both the old world and the new, and had encouraged a developing school of mathematics in the United States to do the same.

[135]Fabian Franklin, "Sur le Développement du Produit infini $(1-x)(1-x^2)(1-x^3)(1-x^4)\ldots$," *Comptes rendus* 82 (1881): 448-450. Parshall and Rowe, p. 122.

[136]Parshall and Rowe, p. 123. This theorem states that "for any positive integer m, the difference between the number of partitions of m into an even number of parts and the number of partitions of m into an odd number of parts equaled $(-1)^n$ if $m = \frac{n(3n\pm1)}{2}$ and zero otherwise." The theorem's name comes from the exponents $m = \frac{n(3n-1)}{2}$, which for $n > 0$ give the sequence of pentagonal numbers, $1, 5, 12, 22, \ldots$ *Ibid.*, pp. 121-123.

[137]*Ibid.*, p. 123.

[138]*Ibid.*, p. 129.

While both Sylvester and Cayley contributed extensively to journals both at home and abroad, Michael and William Roberts relied almost exclusively on foreign periodicals for the publication of their mathematical articles.[139] The Roberts brothers entered Trinity College, Dublin in 1833 and studied under James MacCullagh. The twins remained at Trinity the rest of their lives: William became a Fellow in 1841, while Michael followed suit two years later and, in 1862, was appointed Professor of Mathematics.[140] Soon after obtaining their fellowships, they began contributing mathematical articles to foreign journals and, like many Dublin mathematicians, made their first foreign contributions to Liouville's *Journal.*

Liouville actively promoted the brothers' work, publishing 27 articles by William and eight by Michael. Besides giving them international exposure, Liouville, in a letter to Michael, gave them fatherly advice:

> Please give your brother my compliments, you must enjoy working with him. Imitate the brothers Bernoulli, but not their disputes.[141]

In 1845, the brothers' French mentor announced to the *Bureau des Longitudes* and to the *Académie des Sciences* findings Michael Roberts had derived from Liouville's own work.[142] While looking for a verification of an equation of the geodesics on an ellipsoid which Jacobi had published without a proof in 1839, Liouville had discovered an integral which yielded Michael several results.[143] In an announcement

[139]Of the articles recorded in the *Royal Society Catalogue*, 48 out of 53 of William's and 27 out of 33 of Michael's were made to foreign journals.
[140]Frederic Boase, ed., *Modern English Biography* (London: Frank Cass & Co. Ltd, 1965), s.v. "Roberts, Michael" and "Roberts, William."
[141]Liouville to M. Roberts, 13 March 1847, quoted in Lützen, p. 134.
[142]Lützen, p. 134.
[143]*Ibid.*, p. 700, 714-15.

printed in both his *Journal* and the *Comptes rendus*, Liouville stated that Roberts had demonstrated "very interesting theorems" in "a very simple manner."[144] Liouville's 1846 publication of Roberts's work, along with proofs by Chasles and himself of the integral Liouville had found, inspired a series of papers by Roberts, Liouville, Chasles, and MacCullagh concerning the curves on second-degree surfaces.[145]

Over the next 25 years, the Roberts brothers continued to make frequent international mathematical contributions. Besides Liouville's *Journal*, they published in the *Comptes rendus*, the *Nouvelles annales de mathématiques*, and Crelle's *Journal*, as well as in both incarnations of the *Annali*. Their repeated foreign contributions increased and extended the international reputation of Dublin mathematicians.

Conclusion

Although dominated by the Roberts brothers, Sylvester, and Cayley, this study of British contributions to foreign journals has revealed 47 other internationally active British mathematicians. For the most part, the members of this group received university training from the two mathematical centers of Cambridge and Trinity College, Dublin, they stayed in academia, and they played active roles in scientific societies. A substantial amount of their work began to appear abroad in the 1840s. Many of their initial international articles were fostered and accepted by Joseph Liouville through personal contacts and correspondence. In the other foreign journals in this

[144] Joseph Liouville, "Théorèmes de géométrie par M. Michael Roberts," *Journal de mathématiques pures et appliquées* 10 (1845): 466-468 on p. 466. "Ces théorèmes très intéressants sont surtout relatifs aux lignes géodésiques et aux lignes de courbure que l'on peut tracer sur la surface d'un ellipsoïde à trois axes inégaux... M. Michael Roberts démontre ces théorèmes d'une manière très simple."
[145] Lützen, pp. 714-15.

study's sample, British involvement rose and fell with the appearance of new British mathematicians onto the international scene and with the responses to the international goals of particular journals. A British mathematical presence was most clearly felt in the *American Journal of Mathematics*, partly as a result of the efforts of its first editor, Sylvester. With the *American Journal*, British mathematics would end the century as a central component in a major publication venue of an emerging mathematical community.

As British mathematicians sent their work beyond their country's borders, they increasingly received foreign mathematical contributions for publication in their journals. The proportion of pages occupied by these foreign articles did not grow steadily and never approached the international presence attained by the *Annali*. However, the geographical diversity among the authors of these contributions showed that mathematicians from a variety of countries with established, as well as emerging, mathematical programs recognized British journals as a viable channel for mathematics. Furthermore, the encouragement by influential British mathematicians and societies of international participation reveals that these individuals and organizations recognized the benefits and need of fostering foreign participation in their journals.

It cannot be said that the British mathematical publication community had become completely international by the end of the nineteenth century. However, as this analysis shows, mathematical articles were frequently exchanged and published throughout the century on both sides of the Channel and the Atlantic. The catalysts for this exchange were a concentrated, powerful group of mathematicians with international goals firmly in focus. Their work ensured that British mathematics would trade its earlier reputation of insularity for that of a community unafraid and quite capable of operating on an international scale.

Chapter 7: Mathematical Developments through the Pages of Nineteenth-Century British Scientific Journals

Categorizing a Century of Mathematical Articles: Parameters and Methodology

So far, this investigation of the nineteenth-century British publication community has considered the structure, support, and individuals behind the publication of mathematical articles. In this chapter, we turn to the mathematical contributions themselves. Through a categorization of mathematical articles from a sample[1] of British scientific journals, this chapter measures the publication activity of British mathematicians in 12 fields of mathematics.

The designation of these fields conforms to that of the *Jahrbuch über die Fortschritte der Mathematik.* Carl Ohrtmann and Felix Müller, fellow teachers at the Königlichen Realschule, a German *Gymnasium*, established the *Jahrbuch* in 1868 in order, "on the one hand, to provide for those, who are not in the position to follow independently every new publication in the extensive field of mathematics a means to gain at least a general overview of the development of the science, and, on the other hand,

[1]This sample includes journals supported by scientific societies and individuals and covering general science and specialized science. They are the British Association for the Advancement of Science *Report* (1831-present); Cambridge Philosophical Society *Transactions* (1822-1928); Manchester Literary and Philosophical Society *Memoirs* (1785-1887), *Proceedings* (1857-1887), *Memoirs and Proceedings* (1888-present); Royal Irish Academy *Transactions* (1787-1907); Royal Society of Edinburgh *Transactions* (1783-present); Royal Society of London *Philosophical Transactions* (1665-present), *Proceedings* (1832-present); Edinburgh Mathematical Society *Proceedings* (1883-present); London Mathematical Society *Proceedings* (1865-present); Royal Astronomical Society *Memoirs* (1822-present), *Monthly Notices* (1827-present); *Philosophical Magazine* (1798-present); *Cambridge Mathematical Journal* (1837-1845); *Cambridge and Dublin Mathematical Journal* (1846-1854); *Leybourne's Mathematical Repository* (1806-1835); *Oxford, Cambridge, and Dublin Messenger of Mathematics* (1862-1871); *Messenger of Mathematics* (1871-1929); and *Quarterly Journal of Pure and Applied Mathematics*(1855-1927). We do not consider the proceedings of the transactions of the sections of the British Association that were printed in its *Report*, because they often only summarized articles that were then published elsewhere.

to ease the efforts of the scholar in his search for established knowledge."[2] While the *Fortscritte der Physik*, produced by the Physikalischen Gesellschaft in Berlin, had classified and reviewed articles in physics since 1845, no such review organ existed for mathematics prior to the publication of the *Jahrbuch*.[3] Without the society support enjoyed by the *Fortscritte*, Ohrtmann and Müller created a journal recognized as the preeminent source for mathematical reviews until 1931.[4]

One of the most pressing and difficult challenges facing the founders of the *Jahrbuch* involved the creation of a scheme of categorization for mathematics. Emil Lampe, who assumed the co-editorship of the *Jahrbuch* after Ohrtmann's death in 1885, reflected that "[c]ertainly there is no exhaustive classification of the mathematical disciplines, and although many groups can be easily demarcated on a coarse scale, it is extraordinarily hard to divide all mathematical fields according to a precise uniform scheme. It is also quite easy for one to find fault in a division of too many categories with much too fine, puzzling principles of classification."[5] Out of these concerns, Ohrtmann and

[2] "Vorrede," *Jahrbuch über die Fortschritte der Mathematik* 1 (1871): i-iv on p. i. "Das Ziel, das uns vorschwebte, war einerseits: Demjenigen, der nicht in der Lage ist, alle auf dem umfangreichen Gebiete der Mathematik vorkommenden Erscheinungen selbständig zu verfolgen, ein Mittel zu geben, sich wenigstens einen allgemeinen Ueberblick über das Fortschreiten der Wissenschaft zu verschaffen; andrerseits: dem gelehrten Forscher seine Arbeit bei Auffindung des bereits Bekannten zu erleichtern."

[3] Emil Lampe, "Das Jahrbuch über die Fortschritte der Mathematik. Rückblick und Ausblick," *Jahrbuch über die Fortschritte der Mathematik* 33 (1903): 1-5 on p. 1.

[4] Lampe, p. 1. The Dutch *Revue semestrielle des publications mathématiques* began in 1893, but existed in the shadow of the *Jahrbuch*. Reinhard Siegmund-Schultze, " 'Scientific Control' in Mathematical Reviewing and German—U.S.-American Relations between the Two World Wars," *Historia Mathematica* 21 (1994): 306-329 on p. 308. For the decline of the *Jahrbuch* during the Nazi regime, see *ibid.* The *Jahrbuch*, under stiff competition from the *Zentralblatt für Mathematik und ihre Grenzgebiete* (f. 1931) in Europe and *Mathematical Reviews* (f. 1940) in the United States, finally dissolved in 1945.

[5] Lampe, p. 1. "Bekanttlich gibt es keine erschöpfende Systematik der matematischen Disziplinen, und obwohl manche Gruppen von grösserem Umfange leicht abgegrenzt werden können, so ist es doch ungemein schwierig, alle mathematischen Gegenstände nach einem einheitlichen Schema un-

Müller decided "above all, to strive to create the most efficient guidance possible, and thus an easily accessible survey had to be the chief requirement."[6] Once they had organized their divisions of mathematical fields into the sections of the *Jahrbuch*, the editors adopted a conservative stance regarding any amendments to their classification scheme: "[w]hen someone is accustomed to looking for certain fields in a given chapter, it would be troublesome for him to find those things placed somewhere else."[7] At the same time, however, they tried to make their classification sensitive to mathematical developments: "a careful leader must keep an alert eye on every new appearance, an open ear for all justified complaints; he will readily comply with understandable objections."[8]

The measured editorial policies of the *Jahrbuch* can be seen in a comparison of the classification schemes of the *Jahrbuch* for the years 1870, 1880, 1890, and 1900 (see Table 7A). All of the section headings, with the exception of "Number Theory," remained the same for these volumes, while mathematical developments were reflected in the changing and expanding chapters contained in the sections. These static section headings facilitate the comparison of the subjects of articles throughout the nineteenth-century existence of the *Jahrbuch*.

---

zweideutig zu verteilen. Gar zu leicht gerät man in den Fehler einer Spaltung in zu viele Abteilungen mit allzu fein ausgeklügelten Einteilungsgründen."

[6] *Ibid.*, pp. 1-2. "Bei den vielen Sitzungen, in denen der Plan des Ganzen festgestellt wurde, hielt man besonders an dem Gesichtspunkte fest, dass vor allem eine möglichst rasche Orientierung zu erstreben sei, dass daher die leichte Übersicht das Haupterfordernis sein müsse."

[7] *Ibid.*, p. 2. "Wer einmal gewohnt ist, gewisse Gegenstände in einem bestimmten Kapitel zu suchen, würde es unangenehm empfinden, wenn dieselben Dinge plötzlich anderswo stehen."

[8] *Ibid.* "...ein vorsichtiger Leiter muss ein wachsames Auge auf alle neuen Erscheinungen haben, ein offenes Ohr für alle berechtigen Klagen; er wird verständigen Vorstellungen bereitwillig nachgeben."

Table 7A: Classification Schemes for the *Jahrbuch über die Fortschritte der Mathematik* 1870, 1880, 1890, and 1900.†

1870	1880	1890	1900
I. History and Philosophy			
A. History			
	1. Biographical and Literary 2. History of Disciplines		
B. Philosophy	B. Philosophy (Methodological, Pedagogical)	B. Philosophy and Pedagogy	
		1. Philosophy 2. Pedagogy	
II. Algebra			
A. Equations	A. Equations (General Theory, Specific Algebraic and Transcendental Equations)		
B. Theory of Forms		B. Theory of Forms (Invariant Theory)	
C. Elimination and Substitution, Determinants, Invariants, Covariants, Symmetric Functions	C. Elimination and Substitution, Determinants, Symmetric Functions		C. Substitutions and Group Theory, Determinants, Elimination, Symmetric Functions
			1. Substitutions and Group Theory 2. Determinants 3. Elimination and Symmetric Functions
III. Number Theory		III. Higher and Secondary Arithmetic	
A. General		A. Secondary Arithmetic	
B. Special Series	B. Theory of Forms	B. Number Theory 1. General 2. Theory of Forms	
	C. Continued Fractions		

† Blank entries in this table indicate that no change in the classification scheme occurred during the years of those entries.

Table 7A, continued.

1870	1880	1890	1900
IV. Combinations and Probability			
V. Series			
A. General			
B. Special Series			
VI. Differential and Integral Calculus			
A. General			
B. Differential Equations			
1. Differentials			
2. Functions of Differentials			
3. Maxima, Minima			
C. Integral Equations			
D. Definite Integrals			
E. Ordinary Differential Equations			
F. Partial Differential Equations			
G. Variation Equations			
VII. Function Theory			
A. General Functions	A. General		
B. Special Functions			
		1. Elementary Functions (including the Gamma Functions and Hypergeometric Series)	
		2. Elliptic Functions	
		3. Hyperelliptic, Abelian, and related Functions	
		4. Spherical and related Functions	

Table 7A, continued.

1870	1880	1890	1900
VIII. Pure, Elementary, and Synthetic Geometry			
A. Principles of Geometry			
B. Analysis Situs (Continuity Considerations)			
C. Elementary Geometry			
	1. Planimetry		
	2. Trigonometry		
	3. Stereometry		
D. Descriptive Geometry			
E. New Synthetic Geometry			
1. Plane Constructions		1. General	
2. Space Constructions		2. Special Plane Constructions	
3. Geometry of Number		3. Special Space Constructions	
		4. Constructions in Space of more than 3 Dimensions	
		5. Geometry of Number	
IX. Analytic Geometry			
A. Coordinates			
B. Analytic Geometry of Planes			
1. General Theory of Plane Curves			
2. Theory of Algebraic Curves			
3. Straight Lines and Conic Sections			
	4. Other Special Curves		

Table 7A, continued.

1870	1880	1890	1900
C. Analytic Geometry of Space and Plane Curves			
1. General Theory of Plane Curves			
2. Theory of Algebraic Surfaces and Space Curves			
3. 1^{st}, 2^{nd}, 3^{rd} degree Space Constructions			
4. Other Special Space Constructions			
	5. Constructions in Space of more than 3 Dimensions		
D. Line Geometry (Complex, Ray Systems)			
E. Relations, Clear Transformations, and Constructions			
	1. Relations, Clear Transformations, and Constructions		
	2. Conformal Constructions and the like		
X. Mechanics			
A. General			
B. Kinematics			
C. Statics			
1. Statics of Fixed Bodies			
2. Hydrostatics			
D. Dynamics			
1. Dynamics of Fixed Bodies			
2. Hydrodynamics			
E. Potential Theory			

Table 7A, continued.

1870	1880	1890	1900
XI. Mathematical Physics			
A. Molecular Physics, Elasticity, Capillarity			
		1. Molecular Physics	
		2. Elasticity Physics	
		3. Capillary	
B. Acoustics and Optics			
		1. Acoustics	
		2. Theoretical Optics	
		3. Geometrical Optics	
C. Electricity and Magnetism			
D. Heat			
		1. Mechanical Heat	
		2. Gas Theory	
		3. Heat and Radiation	
XII. Geodesy and Astronomy			
A. Geodesy			
B. Astronomy			
		C. Mathematical Geography and Meteorology	

The *Jahrbuch* scheme divided pure mathematics into the section headings of "Algebra," "Combinations and Probability," "Number Theory" (which changed to the more general title of "Higher and Secondary Arithmetic" in 1884), geometry (which was subdivided into the two headings of "Analytic" and "Pure, Elementary, and Synthetic"), and, finally, analysis (which fell under the headings of "Differential and Integral Calculus," "Function Theory," and "Series"). On the applied side, the *Jahrbuch* organized the headings as "Mechanics," "Geodesy and Astronomy," and "Mathematical Physics." "History and Philosophy," which included pedagogy, completed the classification. Explaining the decision of the editors of the *Jahrbuch* to review these latter areas, Lampe explained that

> Mathematics stands in close contact with the history, the philosophy, and the pedagogy of this science, and it is earlier in many places inseparably bound to physics, astronomy and geodesy, [and] the technical sciences. Especially with the applications of mathematics from the latter group of sciences, it is often hard to find an exact boundary up to which the literature should be considered. According to the principles used as the standard for the *Jahrbuch*, only such works from "applied mathematics" that either discuss important theoretical principles or contain a mathematical treatment of theoretical viewpoints are considered.[9]

While some of the *Jahrbuch* headings seem more or less aligned to modern mathematical taxonomy, others reflect a more properly nineteenth-century view of mathematics, and, for the modern reader, they might benefit from a bit more explanation.

---

[9]Lampe, p. 2. "Mit der Mathematik stehen in enger Berührung die Geschichte, die Philosophie und die Pädagogik dieser Wissenschaft, sind ferner an vielen Stellen untrennbar verbunden die Physik, die Astronomie und Geodäsie, die technischen Wissenschaften. Besonders bei den Anwendungen der Mathematik auf die letztgenannte Gruppe von Wissenschaften ist es oft schwer, eine richtige Grenze zu finden, bis zu der eine Berücksichtigung der Literatur erforderlich ist. Nach den Grundsätzen, welche im Jahrbuche massgebend gewesen sind, werden nur solche Arbeiten aus der 'andgewandten Mathematik' besprochen, welche entweder theoretisch wichtige Prinzipien erörten, oder eine mathematische Behandlung nach theoretischen Gesichtspunkten enthalten."

For example, the enlargement in 1884 of "Number Theory" into "Secondary and Higher Arithmetic" served to separate number theory, also known at the time as higher arithmetic, from more elementary concerns. The *Jahrbuch* translation into English of Gauss's landmark work in number theory, *Disquisitiones Arithmeticae*, is "Investigations in Higher Arithmetic," while it categorizes Micaiah John Muller Hill's "On the Incorrectness of the Rules for Extracting the Square and Cube Roots of a Number" and Charles Pendlebury's textbook, *Arithmetic*, under the subheading of secondary arithmetic.[10]

The nineteenth-century *Jahrbuch* divisions of geometry are also confusing to the modern reader. "Elementary" geometry, like secondary arithmetic, could be applied to the school textbooks on the subject reviewed by the *Jahrbuch*. "Pure" referred to geometry studied in the style of Euclid, and "Synthetic" referred to geometry, especially projective geometry, pursued without the use of algebra or the calculus.[11] Synthetic geometry formed the foil to analytic geometry. Philip Enros has described the meanings of analytics and synthetics that developed beyond the classic meanings of the words: the "main characteristic [of analytics] was the formal manipulation of equations, or expressions; analytics implied an algebraic or formal, operational approach to a topic. The alternative style was synthetics. This was all that was not algebraic. During the latter half of the eighteenth century synthetics came to include

[10]Micaiah John Muller Hill, "On the Incorrectness of the Rules for Extracting the Square and Cube Roots of a Number," *Proceedings of the London Mathematical Society* 18 (1887): 171-178; and Charles Pendlebury, *Arithmetic*, 6th ed. (Cambridge: Deighton, Bell and Co., 1891).

[11]For more on projective geometry, see the overview and case study on analytic geometry below.

all that was not strictly analytic."[12] The author of the article on "Analytical Geometry" in the eleventh edition of the *Encyclopædia Britannica* explained that, in this area, "[i]t is hardly too much to say that, when known facts as to a geometrical figure have once been expressed in algebraical terms, all strictly consequential facts as to the figure can be deduced by almost mechanical processes. Some may well be unexpected consequences; and in obtaining those of which there has been suggestion beforehand the often bewildering labour of constant attention to the figure is obviated. These are the methods of what is now called *analytical*, or sometimes *algebraical*, *geometry*."[13] Despite the author's use of "algebraical" and "analytical" synonymously above, the "Analytic Geometry" of the *Jahrbuch* included both algebraic geometry in the tradition of Descartes as well as differential geometry.[14] The author also betrayed in his article a clear bias towards analytic geometry. In fact, during the nineteenth century, many mathematicians separated into camps supporting the synthetic versus analytic approach to geometry. British views on this division are discussed in a case study below.

The editors of the *Jahrbuch* designed their journal to be efficient, consistent, and useful; the creation of a database that organizes the volumes of the *Jahrbuch* in electronic form has greatly improved all three of these qualities.[15] This database has

[12]Philip C. Enros, "Cambridge University and the Adoption of Analytics in Early Nineteenth-century England," in *Social History of Nineteenth Century Mathematics*, ed. Herbert Mehrtens, Henk Bos, and Ivo Schneider (Boston: Birkhäuser, 1981), pp. 135-164 on pp. 136-137.

[13]*The Encyclopædia Britannica*, 11th ed., 29 vols. (New York: The Encyclopædia Britannica Company, 1910-11), s.v. "Geometry: IV. Analytical Geometry."

[14]For example, the *Jahrbuch* categorizes Gauss's renowned treatise on differential geometry, *Disquisitiones generales circa superficies curvas* under "Analytic Geometry."

[15]This electronic database is maintained by the "Jahrbuch Project Electronic Research Archive for Mathematics" at http://www.emis.de/MATH/JFM/JFM.html.

been used to find and record the *Jahrbuch* classifications of mathematical articles from the British scientific journals in our sample. Thus, the classification of articles from 1868 to 1900 comes from contemporary mathematicians who contributed to a "running chronicle of happenings from the fields of mathematics."[16]

Although this contemporary classification does not exist for mathematical articles before 1868, British mathematical articles that appeared between 1800 and 1867 have been categorized here as consistently as possible with the spirit of the *Jahrbuch* reviewers. This approach has provided a classification scheme that could be extended to the entire nineteenth century.[17] However, without the help of the long departed nineteenth-century *Jahrbuch* reviewers, it is impossible to attain perfect accord between the data for 1868 to 1900 and those for 1800 to 1867. Indeed, any classification decision is by nature subjective. In his classification of mathematical articles by Cambridge mathematicians from 1815 to 1840, Ivor Grattan-Guinness lamented that the classification process is "an exercise in bivalent logic: a paper does or does not gain citation under a given topic. But such judgements are artificial, for we are in the world of degrees rather than yes-or-no; at which point, for example, does a paper on optics give sufficient attention to differential equations to gain a mention there also?"[18] In

[16]Lampe, p. 1. "...es ist eine fortlaufende Chronik aller Geschehnisse auf dem Gebiete der Mathematik."

[17]The section heading "Number Theory" changed to "Higher and Secondary Arithmetic" in the *Jahrbuch* for 1884. This new section heading included "Number Theory" as a chapter. We will use "Higher and Secondary Arithmetic" in our summary of *Jahrbuch* results and our classification of pre-1868 articles, with the understanding that this heading includes number theory for the articles from 1884 to 1900 and is equated with number theory for the pre-1884 articles.

[18]Ivor Grattan-Guinness, "Mathematics and Mathematical Physics from Cambridge, 1815-1840: A Survey of the Achievements and of the French Influences," in *Wranglers and Physicists*, ed. Peter M. Harman (Manchester: University Press, 1985) pp. 84-110 on p. 108. In some cases, the *Jahrbuch* reviewers resorted to classifying an article under more than one heading. In these cases, the articles

spite of these inherent drawbacks, the consistent classification of these articles can provide insight into the changing trends of nineteenth-century British mathematics.

In order to detect changes over time in nineteenth-century British mathematics, a sample of over 8,600 articles has been subdivided into three periods. The first period, 1800-1836, takes as its endpoint the foundation of the *Cambridge Mathematical Journal*, the first of the dynasty of commercial mathematical journals originating at Cambridge.[19] The second period, 1837-1867, marks the interval leading up to and including the foundation of the the London Mathematical Society. The final interval considered, 1868-1900, is convenient since it coincides with the nineteenth-century years covered by the *Jahrbuch*; however, it also comes within a year of coinciding with what Adrian Rice and Robin Wilson have considered as the period in which the London Mathematical Society "consolidate[d] its position as the national society for British research-level mathematicians and ... [took] the first steps towards becoming a major player in the international arena."[20] Like the classification process, the periodization of nineteenth-century British mathematics used here is subject to argument and caters somewhat to the years of existence of the *Jahrbuch*. However, in general, the endpoints of this periodization also reflect significant changes in British mathematical publication venues.

---

are counted repeatedly for each appropriate category in the data that follow.

[19]For more about this journalistic dynasty, recall chapter 4.

[20]Adrian C. Rice and Robin J. Wilson, "From National to International Society: The London Mathematical Society, 1867-1900," *Historia Mathematica* 25 (1998): 185-217 on p. 211.

Charting the Interests of Nineteenth-Century British Mathematicians through their Articles

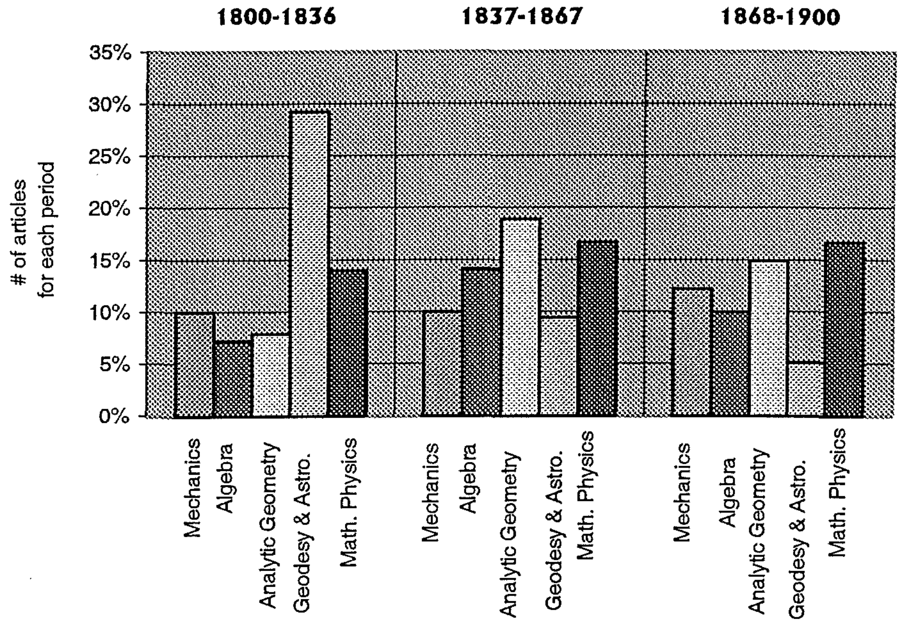
Table 7B uses these three periods to display the percentage of the number of mathematical articles from the sample classified in each of the 12 section headings of the *Jahrbuch*.[21] Table 7C gives a complementary measure of mathematical activity in these subjects by displaying percentages of the number of pages of the articles categorized under each heading. The use of both of these measures gives a more accurate picture of mathematical activity because it takes into account the differing formats of the journals in this sample. For example, the society-supported *Philosophical Transactions of the Royal Society of London* could afford to publish long memoirs and strove for comprehensiveness rather than timeliness. At the other end of the publication spectrum, the financially challenged *Philosophical Magazine* tended to publish shorter notices, a format that also suited the journal's goal to get scientific news to its readers as quickly as possible.[22]

Besides distinguishing between mathematical areas that were more often discussed

[21]This table and Table 7C also include an "Other" category, which counts articles devoted to subjects outside of the 12 section headings such as mathematical machines and mathematical tables. Articles on these topics were listed in the *Jahrbuch*'s appendix.

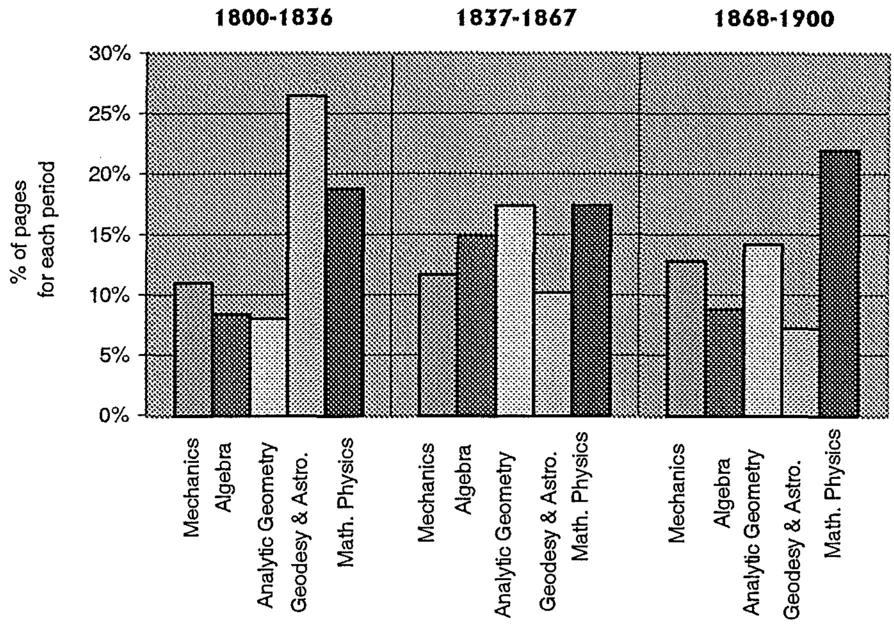
[22]On average, the mathematical articles of the *Philosophical Magazine* were 7.5 pages long while those of the *Philosophical Transactions* were 65 pages long. The averages for the other journals in this sample are: *Transactions of the Royal Society of Edinburgh* (20 pages/article), *Messenger of Mathematics* (5.2), *Proceedings of the Edinburgh Mathematical Society* (7.2), British Association for the Advancement of Science *Report* (not counting the "Transactions" section) (28.9), Cambridge Philosophical Society *Transactions* (23.3), Manchester Literary and Philosophical Society *Memoirs of the Manchester Literary and Philosophical Society* (24.0), *Proceedings of the Manchester Literary and Philosophical Society* (4.1), *Memoirs and Proceedings of the Manchester Literary and Philosophical Society* (9.3), Royal Irish Academy *Transactions* (31.7), *Proceedings of the Royal Society of London* (5.5), *Proceedings of the London Mathematical Society* (13.0); *Memoirs of the Royal Astronomical Society* (28.7), *Monthly Notices of the Royal Astronomical Society* (5.4), *Cambridge Mathematical Journal* (4.1), *Cambridge and Dublin Mathematical Journal* (7.5), *Leybourne's Mathematical Repository* (8.9) (not counting solutions to questions), *Oxford, Cambridge, and Dublin Messenger of Mathematics* (4.6), and *Quarterly Journal of Pure and Applied Mathematics*(9.1).

Table 7B: Most Active Categories: By Number of Articles



	1800-1836	1837-1867	1868-1900
Mechanics	10.0%	10.0%	12.2%
Algebra	7.2%	14.1%	10.0%
Analytic Geometry	7.9%	18.9%	14.9%
Geodesy and Astronomy	29.3%	9.4%	5.1%
Mathematical Physics	14.0%	16.7%	16.7%
Combinations and Probability	2.4%	3.1%	2.8%
Differential and Integral Equations	5.1%	8.2%	9.3%
Function Theory	4.0%	2.8%	8.6%
History and Philosophy	2.2%	2.5%	1.6%
Higher and Secondary Arithmetic	2.9%	3.8%	5.1%
Pure, Elementary and Synthetic Geometry	7.3%	6.3%	9.3%
Series	5.3%	2.5%	3.9%
Other	2.3%	1.8%	0.6%
Total Number of Articles	904	3,302	4,482

Table 7C: Most Active Categories: By Page Length



	1800-1836	1837-1867	1868-1900
Mechanics	11.0%	11.7%	12.8%
Algebra	8.4%	14.9%	8.8%
Analytic Geometry	8.0%	17.4%	14.2%
Geodesy and Astronomy	26.5%	10.2%	7.2%
Mathematical Physics	18.8%	17.4%	22.0%
Combinations and Probability	3.0%	3.2%	3.0%
Differential and Integral Equations	5.8%	8.4%	7.1%
Function Theory	3.3%	3.2%	9.4%
History and Philosophy	1.1%	3.3%	1.3%
Higher and Secondary Arithmetic	1.7%	2.6%	4.9%
Pure, Elementary and Synthetic Geometry	4.9%	4.6%	6.2%
Series	4.7%	2.2%	2.8%
Other	2.6%	0.8%	1.0%
Total Number of Pages	10,694	25,115	52,627

in lengthy memoirs and those more often presented in short articles, this analysis highlights the effect of new publication outlets on mathematical activity. The area of "Pure, Elementary and Synthetic Geometry" provides a good example. It claimed less than 7.3% of the articles for the two periods before 1867 but rose to 9.3% for 1868 to 1900. Similarly, its page percentage, less than 5% for the two earlier periods, increased to 6.2% after 1867. The period of growth for this area, 1868-1900, coincides with the founding of the *Proceedings of the Edinburgh Mathematical Society* and the *Messenger of Mathematics* and the publication of all but the first two volumes of its *Proceedings London Mathematical Society.* Taking these three journals out of the sample, the portion of the number of articles devoted to "Pure, Elementary and Synthetic Geometry" drops 4.3 points to 5.0%.[23] While the establishment of these journals probably did not directly cause British mathematicians to become more interested in this area, they did provide an encouraging outlet for research in this field.

Elementary and pure geometry, as the foundation of the Association for the Advancement of Geometrical Teaching in 1871 indicates, was a subject of much discussion during the last third of the nineteenth century.[24] Recall that this Association objected to the use in geometrical teaching of Euclid's *Elements*, which had for decades been hailed as the standard for British secondary mathematical education. Almost every nineteenth-century British mathematician had received a thorough grounding

[23] "Pure, Elementary and Synthetic Geometry" accounts for 38% of all nineteenth-century reviews of articles from the *Proceedings of the Edinburgh Mathematical Society* and 13.8% for the three journals combined.

[24] For more information on this Association, recall chapter 2.

in geometry à la Euclid or, for the very late nineteenth-century mathematicians, perhaps by a reformed geometrical text. As a common language to these mathematicians and a subject of much pedagogical debate, pure and elementary geometry, not surprisingly, constituted a substantial portion of the mathematics in British scientific journals.

As debates about geometrical pedagogy swirled, interest in Britain about projective geometry also grew. This area was brought to the attention of nineteenth-century mathematicians largely through the work of the French mathematician, Gaspard Monge. Monge, at the École Polytechnique at the turn of the nineteenth century, used cylindrical and central projections to investigate geometry. In the hands of Jean Victor Poncelet, Michel Chasles, and other disciples, Monge's work developed into projective geometry, "the systematic study of those geometrical relations which remain invariant under carefully prescribed processes of projection and section."[25] Although the fundamentals of projective geometry had been explored in the seventeenth century by Girard Desargues and Blaise Pascal,[26] interest in the subject fell during the eighteenth century, and Poncelet's 1822 *Traité des propriétés projectives des figures* was the first text devoted entirely to projective geometry. In order to give pure geometry more generality, Poncelet presented in his *Traité* central projections, homology, birational transformations, transformations by reciprocal polars, and, most

[25] Joan Richards, *Mathematical Visions: The Pursuit of Geometry in Victorian England* (Boston: Academic Press, 1988), pp. 118-119.

[26] Jeremy Gray, "Projective Geometry," in *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences*, ed. Ivor Grattan-Guinness, 2 vols. (London and New York: Routledge, 1994), 2: 897-907 on pp. 899-902.

significantly, the principle of continuity.[27] This principle maintained that a theorem true for a figure remained true for a figure continuously transformed from the original and became a point of dispute about the standard of rigor in synthetic versus analytic methods of geometrical investigation.[28] British mathematicians used both methods, and the synthetic adherents among them had no qualms with the principle of continuity; in fact, "the first elementary English treatment of the subject, published in 1862, rested firmly on the principle."[29]

"Function Theory," like "Pure, Elementary, and Synthetic Geometry," experienced substantial growth in British scientific journals during the last third of the nineteenth century. While the area represented less than 4% of the pages and articles in mathematics for the first two periods of the nineteenth century, after 1867 it jumped to over 9% by both measures. The Oxford mathematician, Henry Smith, noted such a change in his address upon retiring as President of the London Mathematical Society in 1876: "[i]f I had had the honour of addressing the Mathematical Society ten years ago, I think I should have had to complain of the neglect in England of the study of elliptic functions. But I cannot do so now. The University of Cambridge has given this subject a place in its Mathematical Tripos; the University of London in its examination for the Doctorate of Science. The British Association has supplied the funds requisite to defray the cost of printing Tables of the Theta function — Tables of which mathematicians of this country may just be proud... We further owe

[27] *Dictionary of Scientific Biography*, s.v. "Poncelet, Jean Victor."
[28] Richards, *Mathematical Visions*, p. 120.
[29] *Ibid.*, p. 142. This text was John Mulcahy, *Principles of Modern Geometry with Numerous Applications to Plane and Spherical Figures* (Dublin: Hodges and Smith, 1862).

to Professor Cayley an introductory treatise on elliptic functions, the first which has appeared in our language."[30] Besides the tables on the theta function mentioned by Smith, the British Association for the Advancement of Science also published a series of three reports "[o]n Recent Progress in Elliptic and Hyperelliptic Functions," by the London mathematician, William Russell.[31]

"Higher and Secondary Arithmetic" also increased its share of British mathematical articles for the period 1868-1900; however, its gains were much more modest than those of "Function Theory." After occupying 2.6% or less of the pages and 3.8% or less of the articles for the periods before 1868, the area only rose to around 5% by both measures for 1860-1900. The low activity in this area from 1800 to 1867 accords with the following remarks of Smith. While "triumphs achieved in recent times" in England in the fields of algebra and geometry have enticed English mathematicians to work "upon a country which has, we might say, been 'prospected' for us, and in which we know beforehand that we cannot fail to obtain results which will repay our trouble," Smith urged his audience to venture "into regions where, soon after the first step, we should have no beaten tracks to guide us to the lucky spots" because "it cannot be for the interest of science that ... [these areas] should be altogether neglected by the rising generation of English mathematicians."[32] Primary among these "neglected regions," in Smith's opinion, was number theory.

[30]Henry J.S. Smith, "On the Present State and Prospects of Some Branches of Pure Mathematics," *Proceedings of the London Mathematical Society* 8 (1876-1877): 6-27 on p. 26.

[31]W.H.L. Russell, "Report on Recent Progress in Elliptic and Hyperelliptic Functions," *BAAS Report* (1869): 335-360; (1872): 334-359; and (1873): 307-345.

[32]H.J.S. Smith, "On the Present State," p. 8.

Smith had made contributions to number theory that received acclaim on the Continent, earning him the major prizes of both the Paris and Berlin Academies. However, these contributions were largely neglected in Britain. Part of this under-appreciation of Smith's work has been ascribed to the mathematician's modesty, but Hannabuss gives another explanation, namely, that "he worked in such areas as number theory, which were outside the main focus of English mathematics at the time."[33]

The series of six reports that Smith authored for the British Association for the Advancement of Science from 1859 to 1865 also attests to the lack of activity in number theory in Britain.[34] Although these reports aimed to present the results of recent work, open problems, and fertile directions for research in number theory, Smith felt compelled to design his reports to be "intelligible to persons who have not occupied themselves specially with the Theory of Numbers."[35] To that end, he pointed out that "it will be occasionally necessary to introduce a brief and summary indication of principles and results which are to be found in the works of Gauss and Legendre."[36] His citations were made overwhelmingly to continental works and rarely to any of those of his countrymen.[37] Smith's reports gave a clear and comprehensive presenta-

[33]Keith Hannabuss, "Henry Smith," in *Oxford Figures: 800 Years of the Mathematical Sciences*, ed., John Fauvel, Raymond Flood, and Robin Wilson (Oxford: University Press, 2000), pp. 203-217 on p. 203.

[34]Henry J. S. Smith, "Report on the Theory of Numbers," *Report of the British Association for the Advancement of Science* 28 (1859): 228-267; 29 (1860): 120-172; 30 (1861): 292-340; 31 (1862): 503-526; 32 (1863): 768-786; 34 (1865): 322-374.

[35]*Ibid.*, 28 (1859): 229.

[36]*Ibid.*

[37]In fact, in the name index of the *Report on the Theory of Numbers*, a volume containing all of these reports that was published after Smith's death in 1883, there are only two important references to a nineteenth-century British mathematician. Cayley receives this distinction. Of the minor references, six went to Cayley, one to James Glaisher, one to Morgan Jenkins, one to Sylvester, and three to Sir James Wilson. Henry J.S. Smith, *Report on the Theory of Numbers* (1894; reprint ed., New York: Chelsea Publishing Co., 1965).

tion of number theory to British mathematicians, and they no doubt represented a factor in the marginally increased British activity in the area from 1868 to 1900.

"Differential and Integral Calculus" consistently received more attention in British scientific journals than "Higher and Secondary Arithmetic" from the century's beginning. It claimed over 5% of the pages and articles for the period before 1837 then climbed to well over 7% by both measures for the last two periods of the nineteenth century. Concerns stemming from the late eighteenth century about the perceived British isolation from profitable continental techniques incited a diverse group of British mathematicians to reform the British fluxional approach to the calculus. Besides the well-known efforts of the members of the Analytical Society in Cambridge,[38] mathematicians at universities in Scotland, Dublin, and at the military schools of England wrote articles that introduced differential notation and Lagrangian methods to the readers of British scientific journals.[39]

As a result of these efforts, many British mathematicians adapted algebraic methods to the calculus that characterized the Lagrangian approach. One such method that became extremely attractive in Britain was the calculus of operations. At the heart of this method, also known as the separation of symbols, was the analogy between the iteration of symbols of operation to the laws of exponentiation. For example, the "exponent" of $\frac{d}{dx}$, which records how many times differentiation occurs, obeys the law of exponentiation: $\frac{d^a}{dx^a}\left(\frac{d^b y}{dx^b}\right) = \frac{d^{a+b}y}{dx^{a+b}}$.[40] This calculus of operations had

[38]For more on the Analytical Society, recall chapter 4.

[39]Niccolò Guicciardini, *The Development of Newtonian Calculus in Britain 1700-1800* (Cambridge: University Press, 1989), pp. 95-138.

[40]Elaine Koppelman, "The Calculus of Operations and the Rise of Abstract Algebra," *Archive for*

been used by Lagrange and was featured in the Analytical Society's *Memoirs* as well as the notes that former Society members Peacock, Charles Babbage, and John Herschel appended to their translation of Sylvestre Lacroix's *Traité du calcul differentiel et du calcul intégral.*[41]

Contributions on the calculus of operations blossomed during the 1840s and 1850s.[42] While this work led some British mathematicians to consider the algebraic properties of operations, others including Charles Hargreave at University College, London, the Cambridge graduate William Russell, the Oxford graduate William Spottiswoode, and Robert Carmichael at Trinity College Dublin used this method to solve differential equations.[43]

The calculus of operations and other fruits of the early nineteenth-century reform of the calculus, while begun in an effort to end the isolation caused by an adherence to Newtonian fluxions, actually alienated British mathematicians from the rigorization of the calculus being developed by Cauchy. The latter approach to calculus only very slowly established a foothold in Britain.[44] Thus, while differential and integral calculus received significant attention in British scientific journals throughout the nineteenth century, its treatment, based on an algebraic, Lagrangian approach, differed greatly from Cauchy's approach to it on the Continent.

History of Exact Sciences 8 (1971): 155-242 on p. 156.

[41]Guicciardini, p. 137; and Koppelman, p. 181.

[42]Koppelman, p. 200.

[43]*Ibid.*, pp. 200-205.

[44]For more on this integration, see Adrian C. Rice, "A Gradual Innovation: The Introduction of Cauchian Calculus into Mid-Nineteenth-Century Britain," *Proceedings of the Canadian Society for the History and Philosophy of Mathematics* 13 (2000): 48-63.

Most of the limited research on Cauchian-style analysis being published by British mathematicians concerned infinite series.[45] Among these articles is Stokes's 1848 paper in the *Transactions of the Cambridge Philosophical Society* that presented for the first time in print the idea of the uniform convergence of series.[46] However, the fact that work on "Series" occupied less than 5.3% of both the pages and articles for all three periods in Tables 7B and 7C indicates that this British foray into this type of analysis was quite limited.[47]

Like "Series," two other *Jahrbuch* areas experienced little or no growth and only a small presence in British scientific journals during the nineteenth century. "History and Philosophy" as well as "Combinations and Probability" each claimed less than 3.5% of the number of articles and pages for each period.[48] While these areas were neglected in British scientific journals compared to other fields of mathematics, they were not completely ignored by British mathematicians. Augustus De Morgan, for example, conducted well-regarded investigations on the history of mathematics, "dispersed... through short articles in a wide variety of journals and periodicals;" De Morgan's choice to scatter rather than collect his historical work into book form is cited by Adrian Rice as one of the factors behind this work being forgotten by later

[45] *Ibid.*, p. 52.

[46] *Ibid.*, p. 56. George Gabriel Stokes, "On the Critical Values of the Sums of Periodic Series," *Transactions of the Cambridge Philosophical Society* 8 (1848): 533-585.

[47] Andrew Forsyth's book, *Theory of Functions of a Complex Variable*, has been called by Jeremy Gray "the book that brought modern analysis to England," but it was subsequently panned for its lack of rigor. Recall chapter 4. Jeremy Gray, "Mathematics in Cambridge and Beyond," in *Cambridge Minds*, ed. Richard Mason (Cambridge: University Press, 1994), pp. 86-99 on p. 91.

[48] By design, the "Other" category also received consistently low proportions throughout the century.

generations of historians of mathematics.[49] Besides his work on history, De Morgan contributed a "lifelong series of papers and books in which he made notable advances in the ideas and the symbolic representation of logic."[50] Logic, a mathematical area considered by the *Jahrbuch* to lie within the province of philosophy, also received attention from George Boole. In addition to his landmark text, *The Mathematical Analysis of Thought*, Boole published "On the Calculus of Logic" in the *Cambridge and Dublin Mathematical Journal*.[51] He also published several articles on probability,[52] and the combinatorial research of mathematician and military officer, Percy MacMahon, has been categorized as "ahead of his time."[53]

As these examples indicate, Tables 7B and 7C do not detect "singular points," but then they are not designed to do so. This analysis does detect the general trends in mathematical activity fueled by those engaged in the "normal science" described by Thomas Kuhn. Insights from this kind of analysis help fill in the gaps to produce a comprehensive picture of nineteenth-century British mathematics. Moreover, the

[49]Adrian Rice, "Augustus De Morgan: Historian of Science," *History of Science* 34 (1996): 201-240 on p. 232. For De Morgan's historical work on the Newton-Leibniz controversy, and its reception by the Royal Society, recall chapter 2.

[50]G.C. Smith, *The Boole-De Morgan Correspondence, 1842-1864* (Oxford: Clarendon Press, 1982), p. 4.

[51]George Boole, "On the Calculus of Logic," *Cambridge and Dublin Mathematical Journal* 3 (1848): 183-198. An example of De Morgan's articles on logic is Augustus De Morgan, "On the Symbols of Logic, the Theory of the Syllogism, and In Particular of the Copula," *Transactions of the Cambridge Philosophical Society* 9 (1856): 79-127.

[52]For example, George Boole, "Proposed Question on the Theory of Probabilities," *Cambridge and Dublin Mathematical Journal* 6 (1851): 286; "On the Theory of Probabilities and in Particular on Mitchell's Problem of the Distribution of the Fixed Stars," *Philosophical Magazine* 1 (1851): 521-530; "On the Conditions by Which the Solutions of Questions in the Theory of Probabilities are Limited," *Philosophical Magazine* 8 (1854): 91-98; "On the Application of the Theory of Probabilities to the Question of the Combination of Testamonies or Judgments," *Transactions of the Royal Society of Edinburgh* 21 (1857): 597-652; and "On the Theory of Probabilities," *Proceedings of the Royal Society of London* 12 (1862-1863): 420-424.

[53]George E. Andrews, "Preface," *Percy Alexander MacMahon Collected Papers*, vol. 1 (Cambridge, MA and London: The MIT Press, 1978), pp xv-xvii on p. xv.

fact that this analysis represents the collection and classification of *individual* mathematical articles makes it possible to focus in on a particular field, a particular time period, or a particular mathematician or group of mathematicians in order to provide the details to this picture.

It is with a view to the comprehensive picture as well as to the details of nineteenth-century British mathematics in British scientific journals that we now focus on the five most active mathematical areas in nineteenth-century British scientific journals. Here, "most active" is taken to mean those areas with the highest average percentages of page length and article numbers over the three nineteenth-century periods. This definition, rather than one involving the totals for the periods, takes into account the rapid growth in mathematical article publication for the 1837-1867 and 1868-1900 periods. Without normalizing and then averaging the percentages, the activity for 1800-1836 would be almost completely damped by the large numbers of these later periods.

Under the definition of "most active" used here, a group of five areas stands out with respect to both of the measures used here to gauge mathematical activity. The sections that follow discuss British work in the pure mathematical areas of "Algebra" and "Analytic Geometry" as well as the applied areas of "Mathematical Physics," "Mechanics," and "Geodesy and Astronomy."[54] Besides giving general overviews of British activity in each of these areas, these sections employ case studies in order

[54]The average percentages of the number of articles and mathematical pages occupied are: "Algebra" (10.4% of articles; 10.7% of pages), "Analytic Geometry" (13.9%; 13.2%), "Mathematical Physics" (15.8%; 19.4%), "Mechanics" (10.7%; 11.8%), and "Geodesy and Astronomy" (14.6%; 14.6%).

to expose the innovative ideas, personalities, institutions, and journals fueling mathematical developments and trends. Together, the overviews and case studies give insights into British attitudes and approaches to areas of mathematics that claimed almost two-thirds of the mathematical articles and pages appearing in nineteenth-century British scientific journals.

Mechanics and Mathematical Physics: A Nineteenth-Century British Overview

More than any other fields of mathematics, mathematical physics and mechanics attracted the most renowned nineteenth-century British mathematicians. William Thomson (later Lord Kelvin), Stokes, William Rowan Hamilton, James Clerk Maxwell, and George Green, among others, are today memorialized through theorems, equations, and laws. Besides profiting from the creative output of these mathematical stars, mathematical physics and mechanics accounted for one-quarter to one-third of the articles for each of the three periods considered here, making applied or "mixed" mathematics the leading area of nineteenth-century British mathematics. What forces directed this wealth of talent into these applied mathematical fields and encouraged such activity in British scientific journals?

First and foremost, Cambridge University focused nineteenth-century British mathematicians on mathematical physics. From its position as the premier British university for mathematics, Cambridge educated many of the men who went on to make influential contributions in applied mathematics; with the exception of Hamilton, all of the notable applied mathematicians listed above were educated there. Furthermore, the influence of Cambridge spread as its graduates were elected to positions at other British universities;[55] in fact, by the nineteenth century's second half, Cambridge honor graduates occupied almost half of the physical science chairs in those institutions.[56] In light of the pervasiveness of Cambridge graduates in nineteenth-century British applied mathematics, it is appropriate to look at the influence of this university on the development and activity of mathematical physics and mechanics.

The education of nineteenth-century Cambridge students was to a large extent dictated by the content of the Senate House, or Mathematical Tripos, examination.[57] From the beginning of the century, applied or "mixed" mathematical questions dominated this gateway to University honors.[58] Heavily influenced by Newton's *Principia*, these questions tended to cover the more mathematized subjects of mechanics, including hydrostatics and hydrodynamics, astronomy, and especially optics, rather than the mathematically unwieldy areas of heat, electricity, and magnetism.[59]

The design and management of the Mathematical Tripos came from within the colleges of Cambridge, with junior fellows being appointed as examiners and moderators for short, rotational periods.[60] This system allowed, for example, George Peacock, Tripos moderator in 1817, 1819, and 1821, to introduce questions on La-

---

[55] June Barrow-Green, " 'A Corrective to the Spirit of too Exclusively Pure Mathematics': Robert Smith (1689-1768) and his Prizes at Cambridge University," *Annals of Science* 56 (1999): 271-316 on pp. 272-273.

[56] Peter M. Harman, "Introduction," in *Wranglers and Physicists*, pp. 1-11 on p. 1.

[57] For more on the origin, development, and character of this examination, recall chapter 4.

[58] Harvey W. Becher, "William Whewell and Cambridge Mathematics," *Historical Studies in the Physical Sciences* 11 (1980): 1-48 on p. 23.

[59] David B. Wilson, "The Educational Matrix: Physics Education at Early-Victorian Cambridge, Edinburgh and Glasgow Universities," in *Wranglers and Physicists*, pp. 12-48 on pp. 15-16; Becher, "Whewell," p. 6; and Crosbie Smith, " 'Mechanical Philosophy' and the Emergence of Physics in Britain: 1800-1850," *Annals of Science* 33 (1976): 3-29 on p. 21.

[60] Becher, "Whewell," p. 38.

grange's algebraic formulation of the differential calculus that had been advocated by his fellow members of the Analytical Society.[61] While the young Cambridge innovators saw this system as a means to introduce important reforms, William Whewell, Cambridge Professor and later Master of Trinity College, criticized it as enabling the moderators to "constantly write new books, juvenile, hasty, worthless, which take their places in the examinations and exclude all steady standard works."[62]

Whewell's comment reflected a reaction to the proliferation during the 1830s of pure mathematical questions involving the new analytic methods in the Tripos examination. In order to keep mixed mathematics at the fore of the Cambridge curriculum, Whewell successfully argued for the inclusion in the Tripos of such physical topics as heat, electricity, magnetism, the wave theory of light, and capillary action. Even with these additions, questions on pure mathematical topics slightly outnumbered those on mixed mathematics in the 1844 Tripos, and the examination had lengthened from four days in 1827 to a six-day ordeal in 1833.[63] Streamlining was called for, and Whewell worked to ensure that this process would "prevent the establishment of the study of abstract analysis as a discipline independent of, and as prestigious as, mixed mathematics."[64]

In 1849 and 1850, the newly created Cambridge Board of Mathematical Studies,[65] composed of stable professors as opposed to the unpredictable junior fellows,

[61]For more on the reforms advocated by the Analytical Society, recall chapter 4.

[62]William Whewell, quoted in Becher, "Whewell," p. 38.

[63]Becher, "Whewell," pp. 23-24.

[64]*Ibid.*, p. 19.

[65]Initially, the Board had only one pure mathematician, George Peacock, formerly of the Analytical Society, who had become Lowndean Professor. Barrow-Green, "Smith," p. 289.

recommended that the recently introduced topics of heat, magnetism, electricity, and capillary action be removed from the examination.[66] The elimination of these physical topics, which were at any rate only marginally covered on the Tripos,[67] did not imply a loss for Whewell. Instead, these reforms signaled a return to the grounded, stable, physical subjects with reasoning rooted in the *Principia* and a move away from the more hypothetical and experimental areas. On the whole, the reforms tempered the use of the new analytic methods and encouraged more traditional, geometric routes to problem solving; by 1854, applied mathematical questions again outnumbered those in pure mathematics.[68] Adrian Rice has argued that these reforms resulted "in the majority of the best [Cambridge] students after 1850 being applied mathematicians. In fact, thanks to graduates such as Maxwell, Larmor and Thomson, it was applied mathematical topics such as mathematical physics which were the real strength of late-nineteeth-century British mathematics."[69]

Maxwell, in particular, played a significant role in the changes during the last third of the nineteenth century. The 1854 Second Wrangler and first Smith's Prizeman,[70] Maxwell left the natural philosophy chair at King's College, London in 1865 and returned to his *alma mater* as an examiner for the Tripos. In this role, Maxwell helped to reintroduce questions on magnetism, heat, and electricity.[71] The subsequent

[66]Becher, "Whewell," pp. 38-39.

[67]Wilson, "Matrix," p. 16.

[68]Becher, "Whewell," pp. 41-42, 44.

[69]Rice, "A Gradual Innovation," p. 58.

[70]Maxwell actually tied for first with Edward John Routh. For more on Routh, who became one of Cambridge's most renowned Tripos coaches, recall chapter 5.

[71]Romualdas Sviedrys, "The Rise of Physical Science at Victorian Cambridge," *Historical Studies in the Physical Sciences* 2 (1970): 127-151 on pp. 139-140.

need to cover these subjects in the Cambridge curriculum resulted in a committee recommendation to introduce a new professorship of physics with a laboratory. With the unexpected financial help of William Cavendish, Duke of Devonshire, himself Second Wrangler and First Smith's Prizeman, these changes were quickly effected in an institution not known for speedy reform. Maxwell, in fact, was elected to the Cavendish Professorship of Experimental Physics in 1871 and was charged with heading the Cavendish Laboratory, which opened three years later.[72] As Professor of *Experimental* Physics, Maxwell still lectured within the province of the Board of Mathematical Studies. In fact, in spite of the existence of the Natural Science Tripos from 1851 on, it was the Mathematical Tripos through which Maxwell's students came to the Cavendish.[73] Only during the tenure of the third Cavendish Professor, J.J. Thomson, did the Natural Sciences Tripos become the gateway for prospective Cambridge physicists. For almost all of the nineteenth century, Cambridge physics was thus synonymous with 'mixed' mathematics.[74]

Besides the Mathematical Tripos, the Smith's Prizes also encouraged the pursuit of applied mathematics at Cambridge.[75] The examination for these prizes required more original thought, but they covered roughly the same physical ground as those of the Tripos. In his survey of questions from 1835 to 1850, David B. Wilson found that, like the Tripos, the Smith's Prize examination often featured physical optics,

[72] *Ibid.*, pp. 139-141.
[73] Harman, "Introduction," p. 2.
[74] *Ibid.*, p. 2, 11.
[75] For a discussion of these prizes, recall chapter 4.

but seldom posed questions on magnetism, heat, and electricity.[76] George Airy, Professor at Cambridge from 1826 to 1835,[77] worked to introduce the three latter physical subjects into the Prize examination before Whewell advocated similar additions to the Tripos.[78] However, the Smith's Prize examiners soon followed the recommendations of the Board of Mathematical Studies and eliminated these topics from the examination.[79]

Even after he left Cambridge in 1835, Airy used Smith's stipulation that the Prize winners be adept at mathematics *and* natural philosophy to lobby for applied mathematics in the Prize papers. One of his characteristic complaints was of the "pernicious preponderance of a class of pure mathematics" in the examination, and he was often at odds with Cayley, who, as an examiner, introduced many pure mathematical topics.[80] Like Whewell, Airy was successful in keeping applied mathematics central to a curriculum-defining Cambridge examination.

Beginning in 1883, Smith's Prize competitions shifted to written dissertations. While the competitors under the new rules could choose the topics of their essays, the majority of the winners still wrote on themes in applied mathematics.[81] Instead of writing examinations, Cambridge professors now supervised the writing of essays.

---

[76]Wilson, "Matrix," p. 18.

[77]Airy was Lucasian Professor of Mathematics at Cambridge from 1826 to 1828 and Plumian Professor of Astronomy and Director of the Cambridge Observatory from 1828 to 1835. In 1835, he left Cambridge for Greenwich to assume the role as Astronomer Royal.

[78]Barrow-Green, "Smith," p. 288.

[79]*Ibid.*, p. 289.

[80]*Ibid.*, p. 293.

[81]The essays of 18 out of the 35 Smith's Prize winners from 1885 (when the new rules were first implemented) to 1900 concerned applied mathematical topics. Under the new practices, more than two Smith's Prizes per year could be awarded. *Ibid.*, pp. 308-309.

Thus, under both systems, the professoriate was encouraged to stay informed on topics in applied mathematics and to impart this knowledge to its students. In the opinion of June Barrow-Green, this "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."[82]

The influence of researchers in applied mathematics who were trained in Cambridge and went through the rites of passage of the Tripos and Smith's Prize examination extended far and wide throughout nineteenth-century Britain. However, other institutions also shaped the character of the British approach to mathematical physics and mechanics. Due to the incorporation of both experimental and mathematical physics in their natural philosophy courses, professors at the Scottish universities, for example, introduced their students to the less mathematized subjects of heat, electricity, and magnetism earlier than their Cambridge counterparts and without interruption. However, Scottish students' exposure to optics was not nearly as extensive as that of their Cambridge peers.[83] Not surprisingly, then, in his survey of applied mathematical work in early Victorian Cambridge, Edinburgh, and Glasgow, David B. Wilson found that "the Scots...could not match in quantity or quality the Cambridge work in astronomy, mechanics and optics."[84] Instead, Scottish research focused on heat, electricity, and magnetism, areas that the Cambridge researchers neglected.[85] Investigating Cambridge mathematicians from 1815 to 1840,

[82] *Ibid.*, p. 307.
[83] Wilson, "Matrix," p. 34; and Crosbie Smith, pp. 21, 29.
[84] Wilson, "Matrix," p. 39.
[85] *Ibid.*

Ivor Grattan-Guinness also found "quite extensive" Cambridge treatments of optics, hydrodynamics, and hydrostatics and limited Cambridge interest in the three areas of Scottish strength.[86]

William Thomson had a foot in both the Cantabridgian and Scottish worlds of applied mathematics. While he represented the model Cambridge mathematical student as the Second Wrangler and first Smith's Prizeman for 1845, Thomson pursued physical subjects outside the sphere of Cambridge's most important mathematical examinations. Before entering Cambridge, he had also excelled during his years as a student at Glasgow College.[87] Perhaps his tenure in the natural philosophy course of William Meikleham in Glasgow encouraged him to conduct research on heat, magnetism, and electricity even while his close colleague, Stokes, stuck to the traditional Cambridge physical topics.[88]

Back at Glasgow in 1846 as Meikleham's successor in the professorship of natural philosophy, Thomson incorporated his areas of interest into both prize essay contests and his students' laboratory investigations. Soon, he took his lessons on heat, electricity, and magnetism out of the laboratory and brought them into his mathematical

[86]Grattan-Guinness, "Mathematics and Mathematical Physics," pp. 106, 109.

[87]William Thomson began attending classes at the age of ten at the institution where his father was Professor of Mathematics in 1834. He remained there until 1840 and was entitled to a BA but did not take it. Crosbie Smith and M. Norton Wise, *Energy and Empire: A Biographical Study of Lord Kelvin* (Cambridge: University Press, 1989), p. 49.

[88]Sir Leslie Stephen and Sir Sidney Lee, ed., *The Dictionary of National Biography* (London: Oxford University Press, 1885-1901), s.v., "Stokes, George Gabriel" (hereinafter *DNB*). Wilson, "Matrix," pp. 40-41. Stokes had studied before entering Cambridge at Bristol College; its mathematics curriculum was closely aligned with that of Cambridge.

lectures. In fact, by the 1852-1853 session, Thomson presented his recent ideas on thermodynamics.[89]

Like Thomson, Maxwell conducted research outside the traditional realm of Cambridge "mixed" mathematics. After his Cambridge graduation, Maxwell began applying his mathematical training to physical topics more regularly explored in Scotland: electricity and magnetism. His first paper on these topics, "On Faraday's Lines of Force," owed much of its inspiration to his correspondence with Thomson; however, it owed much of its methodology to his Cambridge studies.[90] In it, Maxwell related lines of force to the streamlines of an incompressible fluid by analogy; he then applied these to magnetism and electricity. This "hydrodynamical argument is clearly shaped by his undergraduate study of pressure, motion and equilibrium of fluids. Maxwell established that the mathematical theory of electricity could be incorporated within the explanatory framework of 'mixed mathematics'."[91] One emblematic reflection of Maxwell's debt to his Cambridge days is his use in this paper of a theorem he first saw on his 1854 Smith's Prize examination.[92] Ideas from his first paper on electricity and magnetism reappeared in Maxwell's later development of "the most successful nineteenth-century theory of electromagnetism."[93] Maxwell's passage through the Tri-

[89]Wilson, "Matrix," pp. 31-32.

[90]James Clerk Maxwell, "On Faraday's Lines of Force," *Transactions of the Cambridge Philosophical Society* 10 (1858): 27-83.

[91]Peter M. Harman, "Edinburgh Philosophy and Cambridge Physics: the Natural Philosophy of James Clerk Maxwell," in *Wranglers and Physicists*, pp. 84-110 on p. 211.

[92]Charles C. Gillispie, ed., *Dictionary of Scientific Biography*, 16 vols. and 2 supps (New York: Charles Scribner's Sons, 1970-1990), s.v. "Maxwell, James Clerk" (hereinafter *DSB*). This theorem is discussed below.

[93]Thomas Archibald, "Mathematical Theories of Electricity and Magnetism to 1900," in *Companion Encyclopedia*, pp. 1208-1219 on 1216.

pos and Smith's Prize examination thus provided him with the mathematical tools, but not the areas of research, on which he built his most memorable work.

The Smith's Prize examination certainly inspired Cambridge students to conduct subsequent research in mathematical physics and mechanics; however, the examination could also be a platform for original research. Stokes's Theorem represents the most famous instance of this phenomenon. This theorem, which relates a surface integral evaluated over a surface to a line integral evaluated on its boundary, is one of the most significant of the integral theorems actively developed by Cambridge mathematicians in order to attack physical problems.[94] It first appeared in a July 1850 letter from Thomson to Stokes. Thomson classified the result as "interesting & ... of importance with reference to both physical subjects [namely, electromagnetism and elasticity]."[95] This result first emerged from the two mathematicians' correspondence in the 1854 Smith's Prize examination paper that Stokes prepared for his contestants, Maxwell and Routh:

> 8. If X, Y, Z be functions of the rectangular co-ordinates x, y, z, dS an element of any limited surface, l, m, n, the cosines of the inclinations of the normal at dS to the axes, ds an element of the bounding line, show that

[94] George Green developed his integral theorem before arriving at Cambridge as an autodidactic baker in Nottingham. While he left his study of electricity and magnetism (the context in which he discovered his theorem) behind upon entering Cambridge and turned his attention to the more properly Cambridge subjects of sound, light, and hydrodynamics, Green carried his use of integral theorems to Cambridge. Wilson, "Matrix," p. 40; and J. J. Cross, "Integral Theorems in Cambridge Mathematical Physics, 1830-1855," in *Wranglers and Physicists*, pp. 112-148 on p. 132. Green developed integral theorems in George Green, "On the Laws of Reflection and Refraction of Light," *Transactions of the Cambridge Philosophical Society* 7 (1839): 1-24, 113-120, and "On the Propagation of Light in Crystalline Media," *Transactions of the Cambridge Philosophical Society* 7 (1841): 121-140. For more on the famous theorem that Green formulated in Nottingham, and his subsequent Cambridge hydrodynamical research, recall chapter 4.

[95] William Thomson to G.G. Stokes, 2 July 1850, quoted in Cross, p. 143.

$$\int\int\{l(\frac{dZ}{dy}-\frac{dY}{dz})+m(\frac{dX}{dz}-\frac{dZ}{dx})+n(\frac{dY}{dx}-\frac{dX}{dy})\}dS=\int(X\frac{dx}{dx}+Y\frac{dy}{ds}+Z\frac{dz}{ds})ds$$

the differential coefficients of X, Y, Z being partial, and the single integral being taken all round the perimeter of the surface.[96]

Following a practice established by Airy in 1827, all Smith's Prize papers were published in Cambridge's University Calendar. Thus, Stokes's Theorem first appeared in print in a serial publication firmly within the Cambridge educational sphere. Other Smith's Prize examiners, however, presented their papers to the British mathematical publication community by republishing them in mathematical journals. For example, Airy's papers for 1830 and 1831 appeared in Leybourne's *Mathematical Repository*, and Cayley published his papers in the *Quarterly Journal of Pure and Applied Mathematics*, the *Oxford, Cambridge, and Dublin Messenger of Mathematics*, and the *Messenger of Mathematics*.[97] These articles allowed the wider British mathematical publication community to participate, even if vicariously, in an examination central to the training of Cambridge mathematicians.

Outside the interconnected educational environments of Cambridge and Scotland, other nineteenth-century British mathematicians made significant contributions to mathematical physics and mechanics. In his survey of mathematical research in Ireland from 1782 to 1840, Ivor Grattan-Guinness found that although Irish work on

[96]Smith's Prize Examination Paper, February 1854, quoted in *ibid.*, p. 144.

[97]Barrow-Green, "Smith," pp. 282, 295. George Biddell Airy, "Cambridge Problems 1830, 1831," *Mathematical Repository* 6 (1835): 1-48; Arthur Cayley, "Note on the Composition of Infinitesimal Rotations," *Quarterly Journal of Pure and Applied Mathematics* 8 (1867): 7-10, "A Smith's Prize Paper," *Oxford, Cambridge, and Dublin Messenger of Mathematics* 4 (1868): 201-26; 5 (1869-1870): 40-64, 182-203; "Solutions of a Smith's Prize Paper for 1871," *Messenger of Mathematics* 1 (1871): 37-47, 71-77, 89-95; "On the Representation of a Spherical or Other Surface on a Plane: A Smith's Prize Dissertation," 2 (1872): 36-37; "Two Smith's Prize Dissertations," 2 (1872): 145-149, 161-166; "A Smith's Prize Paper and Dissertation," 3 (1873): 1-4; 165-183, 4 (1874): 6-8; "A Smith's Prize Dissertation," 4 (1874): 157-160; "A Smith's Prize Paper 1877," 6 (1876): 173-182; and "On a Smith's Prize Question, Relating to Potentials," 11 (1881): 15-18.

mechanics was "patchy" and silent on heat diffusion and electromagnetism, Irish interest in optics was "considerable."[98] Graduates of Trinity College, Dublin (TCD), for instance, made significant advances in the theory of light.

Among them, William Rowan Hamilton and James MacCullagh published well-received research on Fresnel's wave surface and conical refractionin the early 1830s.[99] While Hamilton soon turned to questions in algebra, in particular, to applications of his quaternions,[100] MacCullagh continued to conduct notable work in optics.[101] Furthermore, unlike Hamilton, who was relatively isolated from the rest of TCD, MacCullagh, as Professor of Mathematics and then of Natural Philosophy, passed on a tradition of mathematical research to his students.[102]

For example, TCD fellows John Jellett and Samuel Haughton continued MacCullagh's researches on light.[103] In his 1870 presidential address to the Royal Irish Academy, Jellett, who succeeded MacCullagh as Professor of Natural Philosophy at TCD, expressed optimism that the advances in applied mathematics made by MacCullagh, Hamilton, and his own generation would continue in Ireland:

> I would express my earnest hope, that in the Irish Scientific School, the study of this great branch of Science may never be allowed to languish... And if we may be allowed to turn our gaze forward... we may say that in Applied Mathematics we look on the future monarch of the

[98]Ivor Grattan-Guinness, "Mathematical Research and Instruction in Ireland, 1782-1840," in *Science in Ireland 1800-1930: Tradition and Reform*, ed. John R. Nudds *et al.* (Dublin: Trinity College Dublin, 1988), pp. 11-30 on p. 19.

[99]For more on this line of research by Hamilton and MacCullagh and the controversy surrounding it, recall chapter 3.

[100]Spearman, "Mathematics," p. 208.

[101]Spearman, "MacCullagh," p. 46.

[102]Spearman, "Mathematics," p. 211.

[103]A.J. McConnell, "The Dublin Mathematical School," *Proceedings of the Royal Irish Academy* 50 (1944-45): 75-88 on p. 82.

> scientific world... [W]ho can fail to see that the relation of Applied Mathematics to the domain of Science is one of unvarying conquest. Astronomy and Mechanics have long since yielded. Heat, Light, Sound, Electricity, Magnetism, are all but subdued.[104]

As this short overview has demonstrated, throughout nineteenth-century Britain, mathematicians made significant contributions to Jellett's "future monarch of the scientific world." Indeed, research on mathematical physics and mechanics occupied a large portion of the output of the nineteenth-century British mathematical publication community. Although Cambridge's emphasis on "mixed" mathematics was a strong guiding force, researchers in mathematical physics and mechanics came from a variety of educational backgrounds and reacted to the findings and interests of other applied mathematicians. Narrowing the focus now to one publication venue, the *Cambridge and Dublin Mathematical Journal*, the role of a nineteenth-century editor in the encouragement of activity in mathematical physics and mechanics becomes clearly defined.

Case Study: Mechanics and Mathematical Physics in the *Cambridge and Dublin Mathematical Journal* under the Editorship of William Thomson

The articles concerning mathematical physics and mechanics that appeared in the *Cambridge and Dublin Mathematical Journal* during the editorial tenure of William Thomson provide a window into the relationships between applied mathematicians and the rest of mathematical publication community.[105] These articles, appearing

[104]Spearman, "Mathematics," p. 227.

[105]For more on the *Cambridge and Dublin Mathematical Journal*, its predecessor and successor, recall chapter 4, and see Tony Crilly, "The *Cambridge Mathematical Journal* and its Descendants: 1837-1870," pp. 1-34, to appear.

in the first seven volumes of the journal,[106] represented 25.9% of those volumes' articles, and 28.7% of their pages.[107] While the representation of these two areas combined was outnumbered only by articles in the pure area of analytic geometry,[108] the appearance of these applied articles in the *Journal* represented Thomson's efforts actively to encourage and support applied mathematics in his journal.

In these efforts, Thomson steadfastly relied on his friend Stokes. The two men began their lifelong friendship during the first few years of the 1840s at Cambridge, where the recently graduated Stokes remained as a Fellow, and where Thomson was concluding his undergraduate studies. While Thomson left Cambridge for Glasgow shortly after taking over the direction of the *Mathematical Journal*, Stokes remained in Cambridge, and in 1849 was elected Lucasian Professor. Their geographical separation, their interests in similar fields of study, their long lives, and their activity in their emerging profession fostered a fruitful and detailed correspondence, considered by the editor of their letters as "easily the most extensive extant between two Victorian physicists."[109] This correspondence provides an intimate view of the goals,

[106]After the seventh volume, Norman MacLeod Ferrers took over the editorship. Thomson's name still appeared on the *Journal*'s title page, but his role in editing the journal at this point appears to have been minimal. Recall chapter 4.

[107]Besides classifying these 70 articles within the two *Jahrbuch* categories of "Mechanics" and "Mathematical Physics," we can also look at a finer categorization in the *Journal*'s table of contents, where six articles are in optics, 38 in mechanics, one in light and sound, nine in hydrostatics, and 16 in heat, electricity, and magnetism. Interestingly, of these last 16 articles, 12 were written by William Thomson, one by his brother James Thomson, one by Stokes, one by Rankine, and one by Joseph Liouville. Stokes here is the only contributor to heat, electricity, and magnetism who had been wholly trained within the Cambridge educational framework. For more on Thomson's relationship with Liouville, recall chapter 6.

[108]For these volumes, articles on analytic geometry represented 28.1% of the articles and 28.6% of the pages in the *Journal*.

[109]David B. Wilson, ed., *The Correspondence Between Sir George Gabriel Stokes and Sir William Thomson, Baron Kelvin of Largs*, 2 vols. (Cambridge: University Press, 1990), 1: xv.

motivations, complications, and lamentations behind the articles on mathematical physics and mechanics in the *Cambridge and Dublin Mathematical Journal.*

Together, Thomson and Stokes provided almost 40% of the articles on these two areas to the *Journal.*[110] In making these contributions, they sought both to boost the *Journal*'s applied mathematical coverage and to encourage its readers to pursue applied mathematical subjects. For example, Thomson told Stokes in October of 1847 that he had "written a few pages on the equation of continuity for the forthcoming N° of the Journal, and I have actually been bold enough to entitle it 'Notes on Hydrodynamics, N° 1.' Hence I must get some more notes, perhaps from you."[111]

In this first installment, Thomson provided a proof of the idea that the difference of the amounts of fluid flowing into and out of a space S during a given time interval accounts for the change in the mean density of the fluid in that space during that interval, and, consequently, if the mean density does not change, then the amount of water flowing in equals that flowing out. He found this proof "simpler than that which is generally given in treatises on Hydrodynamics" and noted that "it has been frequently given in lectures at Cambridge, and elsewhere, and it is likely to occur to any one reading Fourier's Theory of Heat; but I am not aware that it has been hitherto published in any work except Duhamel's *Cours de Méchanique.*"[112] Thus, Thomson brought a hydrodynamical development from the texts of France and lecture halls of

[110]They contributed 41.5% of the pages on these areas.
[111]William Thomson to G.G. Stokes, 20 Oct. 1847, Stokes Papers, Cambridge University Library, in Wilson, *Correspondence*, 1: 30.
[112]William Thomson, "Notes on Hydrodynamics I: On the Equation of Continuity," *Cambridge and Dublin Mathematical Journal* 2 (1847): 282-286 on p. 282.

Cambridge to his readers.

Thomson went on to fill what he considered deficiencies in the hydrodynamical education of his audience in his second note "On the Equation of the Bounding Surface." A treatment of the differential equation of the surface bounding a fluid mass in motion "ought to find a place in a complete treatise on the mathematical theory of hydrodynamics. It is wanting in many of the elementary works, and this paper may therefore be considered to be useful as supplying the deficiency."[113]

Stokes responded to Thomson's two notes positively, writing that "I like your Hydrodynamical programme very much & ... I hope we shall have something of it in each N° for some time, as I am sure it will call attention to a most interesting & much neglected subject."[114] Stokes was a good choice for a contributor for Thomson's hydrodynamical series. An 1846 report on hydrodynamics that Stokes had given to the British Association for the Advancement of Science was immediately well-received and provided a boost to his young scientific reputation.[115] For his part, Stokes submitted a third note "On Dynamical Equations."[116] Evidence of the informal relationship, certainly not that of editor and contributor, between the two men can be seen in Thomson's alterations to the standard editor's form letter that he sent Stokes upon receiving his paper.

[113]William Thomson, "Notes on Hydrodynamics II: On the Equation of the Bounding Surface," *Cambridge and Dublin Mathematical Journal* 3 (1848): 89-93 on p. 90.

[114]G.G. Stokes to William Thomson, 5 Feb. 1848, Stokes Papers, Cambridge University Library, in Wilson, *Correspondence,* 1: 46.

[115]*DSB* s.v. "Stokes, George Gabriel."

[116]G.G. Stokes, "On the Dynamical Equations," *Cambridge and Dublin Mathematical Journal* 3 (1848): 121-127.

> The Editor of the *Cambridge and Dublin Mathematical Journal* thanks Mr. *Stokes* for his *very pleasant* communication dated *Feb. 17*. ~~Should~~ his *uncommonly jolly* paper ~~be considered suitable for insertion in the Journal, a notice regarding it~~ will appear in the next Number; ~~otherwise the Manuscript will be returned as soon as possible~~.[117]

Stokes also provided the fourth installment of the hydrodynamical series, in which he gave two proofs of "a fundamental theorem." Like his third note, this communication took as its object the explanation of the relationships "between the changes of motion which take place in the system and the forces producing such changes."[118] In his proofs of this theorem on point forces,[119] Stokes used a demonstration by Cauchy that "does not seem to have attracted the attention which it deserves."[120] The second demonstration was Stokes's own, a proof that he had originally published in the *Transactions of the Cambridge Philosophical Society*.[121] This note then represented an educational exposition rather than the presentation of new research.

Stokes had similar educational goals for the sixth and final hydrodynamical note in the *Cambridge and Dublin Mathematical Journal*,[122] considering his audience as university students instead of colleagues. In a letter to Thomson, he wrote that "I send you my long promised paper on waves. It has run to a greater length than I expected, but as it was meant for the *men* not for the *philosophers* I thought it best

---

[117] William Thomson to G.G. Stokes, Stokes Papers, Cambridge University Library, Add 7656, 18 Feb. 1848. Also in Wilson, *Correspondence*, 1: 47. The slanted writing indicates additions that Thomson wrote in his own hand.

[118] Stokes, "On the Dynamical Equations," p. 122.

[119] Smith and Wise, p. 273.

[120] G.G. Stokes, "Notes on Hydrodynamics IV: Demonstration of a Fundamental Theorem," *Cambridge and Dublin Mathematical Journal* 3 (1848): 209-219 on p. 217.

[121] G.G. Stokes, "On the Theories of the Internal Friction of Fluids in Motion, and of the Equilibrium and Motion of Elastic Solids," *Transactions of the Cambridge Philosophical Society* 8 (1847): 287-319.

[122] The fifth installment of this series was William Thomson, "Notes on Hydrodynamics V: On the Vis-Viva of a Liquid in Motion," *Cambridge and Dublin Mathematical Journal* 4 (1849): 90-95.

to be pretty full."[123] In this note, Stokes gave a theory of "long waves," whose length is much greater than the depth of their fluid of propagation, and "oscilatory waves" produced by wind on the water's surface. These two cases, Stokes explained, are "especially worthy of attention" unlike the waves considered by Cauchy and Poisson, whose conditions are "seldom possible to realize in experiment."[124] Thus, the treatments of the French mathematicians, which might discourage a student from their "mathematical difficulties of a high order," could be avoided and replaced with the study of two classes of waves whose theory was "sufficiently simple."[125]

Besides contributing to Thomson's program of hydrodynamics, Stokes frequently performed many of the day-to-day editorial tasks for the *Journal.* In Cambridge with the printers, Stokes often handled the technical details that Thomson could not effectively perform in Glasgow. For example, for one number of the *Journal*, Thomson wrote Stokes that he had "directed the printers ... to send you a proof of the cover. You will oblige me much (and the British mathematical public too by so allowing the Number to appear at the promised time or within 24 h. of it) by glancing at the Table of contents and at the notices just to see that there is nothing absurd."[126]

Stokes's unofficial service as liaison with the printers at Macmillan[127] becomes es-

[123] G.G. Stokes to William Thomson, Kelvin Papers, Cambridge University Library, 22 Mar. 1849, in Wilson, *Correspondence*, 1: 68.

[124] G.G. Stokes, "Notes on Hydrodynamics VI: On Waves," *Cambridge and Dublin Mathematical Journal* 4 (1849): 219-240 on pp. 219-220. The problem considered by Cauchy and Poisson was the "determination of the motion of a mass of liquid of great depth when a small portion of the surface has been slightly disturbed in a given arbitary manner." *Ibid.*, p. 220.

[125] *Ibid.*, p. 221.

[126] William Thomson to G.G. Stokes, Stokes Papers, Cambridge University Library, 29 Apr. 1849, in Wilson, *Correspondence*, 1: 75.

[127] For more on Macmillan's relationship with the *Journal*, recall chapter 4.

pecially clear concerning an article by the Edinburgh mathematician, Andrew Bell.[128] In November 1847, Thomson asked Stokes to inquire at the printers about Bell's paper, which he was quite uneasy about publishing:

> There is a most absurd paper (fortunately very short) of Bell's "On the Modulus of Elast$^{\underline{y}}$ of a rod as det$^{\underline{d}}$ by its musical note" w$^{\underline{h}}$[ich] I have committed myself, to print. I must put in some sort of note as a *protest* along with it. It is at present in the Macmillan's hands. They were to send it to me (as I wished to see it again before publishing it) but I fear they have neglected my commision. Will you get it from them if they have not sent it to me & after glancing at it, post it for me, yourself?[129]

In this paper, Bell proposed to use the musical note emanating from a rod of material to determine its modulus of elasticity. He claimed that this method could be used to find the weight that a column of this material could withstand before bending.[130] Bell then stated that the notes from a rod would be proportional to the velocity of the propagation of waves through it; this velocity, in turn, is directly related to the modulus of elasticity, if there is "no disengagement of free caloric by the undulatory condensations."[131] These complications, however, are present in this situation and accelerate the velocity of the propagation of waves "in some measure."[132] It is this point of uncertainty that Thomson diplomatically attacked; in his editor's note, he

[128]The prosopographical study in chapter 5 included no information on Andrew Bell: the fact that he lived in Edinburgh simply comes directly from his articles. An Andrew Bell applied for the Chair of Mathematics at the London University (later, University College, London) in June 1827. However, he was passed over for Augustus De Morgan. Adrian C. Rice, "Augustus De Morgan and the Development of University Mathematics in London in the Nineteenth Century," (unpublished PhD dissertation, Middlesex University, 1997), p. 63.

[129]William Thomson to G.G. Stokes, Stokes Papers, Cambridge University Library, Add 7656, 28 Nov. 1847. Also in Wilson, *Correspondence*, 1: 40.

[130]Andrew Bell, "On the Determination of the Modulus of Elasticity of a Rod of any Material, By Means of its Musical Note," *Cambridge and Dublin Mathematical Journal* 3 (1848): 63-67 on pp. 63-64.

[131]*Ibid.*, p. 65.

[132]*Ibid.*, p. 67.

wrote that "[o]ur ignorance of the amount of this effect, and our consequent inability to make the necessary correction for it, are such that the practical application suggested in this paper, cannot, in the present state of science, be considered as likely to lead to very accurate results."[133] Thomson wanted to encourage the publication of articles on mathematical physics and mechanics in his journal, and he, no doubt, did not want to alienate Bell, a supporter of his journal. In the precarious world of commercial journal publication, Thomson could not afford to make enemies. However, as his remarks show, Thomson felt that he had to balance these factors with his desire for high journalistic standards.[134]

Thomson's standards applied not only to the minor submissions of contributors like Bell but also to substantial articles by men who were well-regarded for their contributions to physics. For example, in February of 1851, Thomson asked Stokes to referee part of a paper submitted by W.J. Macquorn Rankine,[135] "one of the most original, if speculative and enigmatic physicists of the 1850s."[136]

After studying at the University of Edinburgh, Rankine had become an apprentice to a civil engineer, and subsequently worked for railroad and harbor concerns. He only reentered academia in 1855, when he assumed the professorship in civil engineering and mechanics at Glasgow. During the years he worked outside of academia as an engineer, however, Rankine was not an outsider to the British scientific community.

[133]William Thomson, [Editor's Note], *Cambridge and Dublin Mathematical Journal* 3 (1848): 67.

[134]For more on Thomson's editorial decisions, recall chapter 4.

[135]William Thomson to G.G. Stokes, Stokes Papers, Cambridge University Library, 25 Feb. 1851, in Wilson, *Correspondence*, 1: 115.

[136]Crosbie Smith, p. 28.

He was elected as a Fellow of the Royal Society of Edinburgh in 1849 and of the Royal Society of London four years later.[137]

Thomson acted as the referee for Rankine's 1850 paper "On the Mechanical Action of Heat, Especially in Gases and Vapours" to the Royal Society of Edinburgh.[138] In this paper, Rankine demonstrated how the convertibility of heat and work could be explained by a dynamical theory of heat.[139] He presented this illustration in the context of his molecular vortex hypothesis, which also played a central role in his *Cambridge and Dublin Mathematical Journal* contribution and is discussed below. Rankine considered some of the same questions discussed by Rudolph Clausius, *Privatdozent* at the University of Berlin. In an April 1850 article in Poggendorff's *Annalen*, Clausius published his version of the second law of thermodynamics.[140] Less than a year later, Thomson announced his own version of this law to the Royal Society of Edinburgh: "it is impossible, by means of inanimate material agency, to derive mechanical effect from any portion of matter by cooling it below the temperature of the coldest of the surrounding objects."[141]

[137] "Obituary Notices of Fellows Deceased," *Proceedings of the Royal Society of London* 21 (1872-1873): i-iv on p. i, iv.

[138] W.J. Macquorn Rankine, "On the Mechanical Action of Heat, Especially in Gases and Vapours," *Transactions of the Royal Society of Edinburgh* 20 (1853): 147-190.

[139] Smith and Wise, p. 321.

[140] Rudolf Clausius, "Ueber die bewegende Kraft der Wärme," Poggendorff's *Annalen* 79 (1850): 368-394, 500-524. In his statement of the Second Law of Thermodynamics, Clausius argued "that if there were some working substance, or engine, to provide more work for the fall of a given amount of heat than another engine; or, what amounts to the same thing, were it to provide the same work for the fall of a smaller amount of heat, then if the first engine drives the second one in reverse we would have an entirely anomalous result: no net work would be done and heat would, in effect, flow from a cold to a hot body. This, he postulates, is quite impossible." D.S.L. Cardwell, *From Watt to Clausius* (Ithaca: Cornell University Press, 1971), p. 247.

[141] William Thomson, quoted in Smith and Wise, p. 329. William Thomson, "On the Dynamical Theory of Heat," *Transactions of the Royal Society of Edinburgh* 20 (1853): 261-289.

While Thomson was aware of Clausius's work, its effect on his investigations is not clear. The effect of Rankine's work on Thomson during this period was, however, "crucial" in the opinion of two of Thomson's biographers: "Rankine's concrete model of heat as *vis viva* [i.e., kinetic energy] helped Thomson to accept the mutual convertibility of heat and work, abandoning the state-function view of heat which required no net loss or gain during the production of mechanical effort in cyclic processes. Even though Thomson did not accept Rankine's *specific* mechanical hypothesis of the nature of heat, he was soon prepared to accept a *general* dynamical theory of heat, namely that heat was *vis viva* of some kind."[142] For his role in the development of the theory, for his introduction of the entropy function in 1854, and for his subsequent application of the theory to heat engines, Rankine was recognized by his contemporaries, along with Thomson and Clausius, as one of the three founders of thermodynamics.[143]

The 1851 paper on the "Laws of Elasticity of Solid Bodies" that Rankine submitted to Thomson's *Journal* considered the laws of elasticity in reference to the strength of structures just as Bell had discussed earlier. Instead of advocating a suspect application of musical notes to practical problems, however, Rankine considered a possible simplification of these laws using his molecular vortex hypothesis. This hypothesis, Rankine explained,

[142]Smith and Wise, p. 320, 327.

[143]Peter Guthrie Tait, "Memoir," in W.J. Macquorn Rankine, *Miscellaneous Scientific Papers*, ed. W.J. Millar, (London: Charles Griffin & Co., 1881), pp. xix-xxxvi on pp. xix-xx; and Keith Hutchison, "W.J.M. Rankine and the Rise of Thermodynamics," *British Journal for the History of Science* 14 (1981): 1-26 on p. 1. For the factors behind the little attention given to Rankine's role in the development of thermodynamics by modern scientists, see Hutchison.

> ...assumes, that each atom of matter consists of a nucleus or central physical point, enveloped by an elastic atmosphere, which is retained in position by forces attractive towards the atomic centre, and which, in the absence of heat, would be so much condensed round that centre as to produce the condition of perfect solidity in all substances: that the changes of condition and elasticity due to heat arise from the centrifugal force of revolutions among the particles of the atmospheres, diffusing them to a greater distance from their centres, and thus increasing the elasticity which resists change of volume alone, at the expense of that which resists change of figure also.[144]

This model of nuclei surrounded by vortices of motion allowed Rankine "to connect macroscopic elasticity with microscopic rotation"[145] and simplified the causes of elasticity to the forces between nuclei, the centrifugal force of the vortices, and ambiant elasticity.[146]

Recall that Rankine's *Cambridge and Dublin Mathematical Journal* contribution on elasticity was not his first memoir to cross Thomson's desk. While influential in Thomson's conception of the dynamical theory of heat, Rankine's paper to the Royal Society of Edinburgh had not escaped the referee without criticism about Rankine's use of the molecular vortex hypothesis.[147] Neither did Rankine's submission to Thomson's *Journal* avoid criticism.

At issue was Rankine's proof of the theorem "that in a given plane in an elastic solid consisting entirely of atoms acting on each other by attractions, and repulsions between their centre, the coefficients of rigidity and of lateral elasticity are equal."[148] In a somewhat bristly letter accompanying his "remodelled ...short supplementary

[144]W.J. Macquorn Rankine, "Laws of the Elasticity of Solid Bodies," *Cambridge and Dublin Mathematical Journal* 6 (1851): 47-80 on p. 67.
[145]Hutchinson, pp. 4-5.
[146]*Ibid.*, p. 5.
[147]Smith and Wise, p. 323.
[148]Rankine, "Laws of the Elasticity," p. 179.

paper," Rankine gave an explanation of "[t]he points as to which you misconceived my reasoning in the former edition of it."[149] While this response showed no recognition of a mistake on his part, Rankine did concede that "I am now conscious that I did not at first express myself with sufficient clearness."[150]

The proof in question rested on a principle that Rankine had earlier presented, he explained, "without demonstration. The editor of this *Journal*, however, has since shewn me, that my having done so may be considered as causing a defect in the chain of reasoning."[151] Stokes acted as the referee for this proof[152] to insure that the principle Rankine had presented earlier as "granted" would be placed on a firmer theoretical footing.

Besides those in applied fields like Rankine, men who have come to be known as pure mathematicians also contributed to the mathematical physics and mechanics sections of Thomson's *Journal*. In 1846 and 1847, Thomson praised the work of both Boole and Cayley on physical subjects with such comments as "Exceedingly good" and "a subject in which I am much interested."[153] Boole hoped that some of his Irish colleagues would also add to the applied sections of the *Journal*: "I hope you will get Sir. W. Hamilton and Graves[154] as allies. They will soon I should think get through

[149] W.J. Maquorn Rankine to William Thomson, Cambridge University Library, Add.7342, 15 Feb. 1851.
[150] *Ibid.*
[151] *Ibid.*
[152] Smith and Wise, p. 400.
[153] William Thomson, quoted in Smith and Wise, p. 188
[154] Smith and Wise identify this Graves as John, a law scholar and avocational mathematician who was a good friend of Hamilton's. Smith and Wise, p. 188. Both John and his brother Charles Graves, Professor of Mathematics at TCD, were involved in developing the triplet system, based on roots of unity. *DNB*, s.v., "Graves, Charles," and "Graves, John Thomas."

their quaternions and triplets and interesting as the subject is I must confess that I should be glad to see them turning their attentions to the Int[egral] Calc[ulus] and to physical sciences."[155]

Boole's encouragement of Cayley to turn his mind towards optics yielded Cayley's *Journal* contribution "On the Caustic by Reflection at a Circle."[156] In it, Cayley presented an equation for the "locus of a curve generated by the continued intersections" of lines describing the reflected ray derived from a "luminous point" (a, b) being reflected on a circle of radius k at the point (ξ, η).[157] Displaying his wide reading of international works, Cayley explained that his solution was a slight variation on that published by the French engineer, Jean Claude Barré de St. Laurent in Gergonne's *Annales.*

This article would be Cayley's only optical foray in the *Journal*, and his reluctance to delve too deeply into the subject appears in his response to Boole that "Physical Optics seems to be a fatally seducing subject, it has attracted so many to itself just now: my only acquaintance with the sort of analysis that occurs in it, is derived from the theory of heat — & some memoirs of Cauchy's that I have looked thro' sufficiently to get an idea of them without properly studying them."[158]

---

[155]George Boole to William Thomson, Add 7342, Kelvin Papers, Cambridge University Library, 6 Aug. 1845. For more on the Irish contributions to the *Journal*, recall chapter 4. Neither Graves brother published in Thomson's *Journal*. While Hamilton published "On Symbolical Geometry" and "Exercises in Quaternions" in the *Journal*, no applied papers by him appear in the first seven volumes.

[156]Tony Crilly, *Arthur Cayley, Mathematician Laureate of the Victorian Age*, preprint, chapter 6, p. 14. Arthur Cayley, "On the Caustic by Reflection at a Circle," *Cambridge and Dublin Mathematical Journal* 2 (1847): 128-129.

[157]Cayley, pp. 128-129.

[158]Arthur Cayley to George Boole, 14 December, 1846, quoted in Crilly, *Mathematician Laureate*, chapter 6, p. 14.

Despite his hesitance to pursue optics, Cayley was the second most active contributor to the mathematical physics and mechanics portions of the first seven volumes of the *Journal*, with only Thomson topping his number of papers in these areas.[159] This ranking seems less surprising in light of the fact that Cayley was by far the most prolific contributor to the *Journal* for these years with 47 contributions. This prodigious activity, for which Cayley would become known, is illustrated in Cayley's casual comment in a letter to Thomson that "I have 14 papers for you — which I will not trouble with just now, as you seem to have stock enough."[160] While he was primarily drawn to topics in pure mathematics, "[w]ith the precocious energy of a young and very ambitious mathematician he flitted from one subject to another, as each competed for his attention."[161] Besides energy and ambition, the "mixed" mathematical education Cayley received at Cambridge facilitated these flirtations in applied mathematics.[162]

Thomson's praise in 1847 for Cayley's applied mathematical contributions to his *Journal* formed a sharp contrast to his complaint to Hermann Helmholz in an 1864

[159]Thomson made 21 contributions in these areas, while Cayley made ten. In third place was Stokes with nine.

[160]Arthur Cayley to William Thomson, 4 December, 1846, quoted in Crilly, *Mathematician Laureate*, chapter 6, p. 14.

[161]Crilly, *Mathematician Laureate*, chapter 5, p. 1.

[162]Other Cambridge-educated mathematicians remembered today for their pure mathematical research found themselves well-equipped to delve into applied mathematics throughout their careers. For example, Sylvester published papers on continuum mechanics, projectile theory, the theory of embankments, dynamics, and rectilinear linkages, while William Burnside published on hydrodynamics, potential theory, and the kinetic theory of gases. For Sylvester's applied work, see Ivor Grattan-Guinness, "The Contributions of J.J. Sylvester to Mechanics and Mathematical Physics," *Notes and Records of the Royal Society of London* 44 (2001): 253-265. For Burnside, see June Barrow-Green, "William Burnside's Applied Mathematics," in *The Collected Papers of William Burnside*, ed. Peter M. Neumann, A.J.S. Mann, and J.C. Thompson (Oxford: University Press), to appear.

letter regarding elasticity: "Oh! That the CAYLEYS would devote what skill they have to such things instead of to pieces of algebra which possibly interest four people in the world, certainly not more, and possibly also only the one person who works. It is really too bad that they don't take their part in the advancement of the world."[163] This frustration surfaced earlier when Thomson was editing the *Journal.* In 1851, he lamented to Stokes that "I shall be very glad to get publishing your paper in the Journal, as I am very desirous of getting such papers on physical subjects sometimes in place of the endless algebra & combinatorics wh.[ich] so abound."[164] Indeed, as early as 1847, Thomson's frustration by the lack of applied contributions to the *Journal* tempted him to quit as editor.[165]

Thomson eventually did pass his editorial torch to Norman Ferrers in 1852, after unsuccessfully trying to convince Stokes to take over the direction of the *Journal.*[166] The little attention given mathematical physics and mechanics in the two volumes of the *Journal* edited by Ferrers further underscores the efforts that Thomson made while editor to encourage applied contributions.[167] Smith and Wise claim that this change represented the effective formalization of "the division that had been emerging for some time between mathematicians and mathematical physicists;"[168] at the very least, the change reflected the power of a motivated editor to shape the character of

[163]William Thomson to Hermann Helmholtz, 31 July, 1864, quoted in Smith and Wise, p. 189.

[164]William Thomson to G.G. Stokes, Stokes Papers, Cambridge University Library, Add 7656, 25 February 1851. Also in Wilson, *Correspondence*, 1: 114.

[165]Smith and Wise, p. 188.

[166]For more on this editorial transition, recall chapter 4.

[167]For volumes 1-7, mathematical physics and mechanics represented 28.7% of the pages of the *Journal.* For Ferrers's volumes (8-9), this percentage dropped to 9.2%.

[168]Smith and Wise, p. 190

his journal.

An Overview of Astronomy and Geodesy in Nineteenth-Century Britain

In the year 1800, Britain could claim many stunning successes in astronomy. Most notably, the work of William Herschel and his sister, Caroline, had resulted in new insights into nebulae and double stars and, most surprisingly, the discovery of Uranus in 1781.[169] In evaluating the Herschels' accomplishment, Agnes M. Clerke commented that "[s]uccess swells the ranks of an invading army;"[170] indeed, Tables 7B and 7C show that the army that formed around the Herschels' observational triumphs also spilled over into mathematical astronomy and geodesy, which accounted for over one-fourth of the mathematical articles and pages in British scientific journals from 1800 to 1836. However, by the last third of the nineteenth century, the claim of astronomy and geodesy in these journals dropped to around 6%.[171] Why did astronomy and geodesy dominate the mathematical pages of British journals early in the century but then later occupy only a modest proportion of this venue? This overview suggests some possible answers to this question while it traces the development of this area over the nineteenth century.

William Herschel has been described as "a man of an irrepressible experimental talent that counterbalanced the brilliance of contemporary theoretical astronomy, especially that in France."[172] In fact, some British mathematicians at the turn of the

[169]For a classic account of the Herschels' work, see Agnes M. Clerke, *The Herschels and Modern Astronomy* (London: Cassell and Co., 1895). For more on Caroline Herschel, see Marilyn Bailey Ogilvie, "Caroline Herschel's Contributions to Astronomy," *Annals of Science* 32 (1975): 149-161.
[170]Clerke, p. 112.
[171]Unless specified as observational astronomy, "astronomy" in this section refers to mathematical astronomy.
[172]John North, *The Norton History of Astronomy and Cosmology* (New York and London: W.W.

nineteenth century felt a need to import rather than counterbalance French innovations in mathematical astronomy. Looking back on the situation in 1832, Airy drew a connection between outdated British mathematical methodology and an earlier decline in astronomy: "I am not one of those who have joined in the cry of 'decline of science in England,' nor do I believe that in this science there is any foundation for that cry... That there has been a decline, thirty or forty years ago, or rather that we have not kept up with the advances made by foreigners at that time, I am willing to admit. Perhaps this arose from political separation; perhaps in some degree from our pertinaciously retaining a system of mathematics which was insufficient for the deep investigations of Physical Astronomy (for it was in this principally that we were behind our neighbours)."[173] These opinions were not only held retrospectively. Recall that the 1808 polemic about the ignorance of British mathematicians of continental methods by the Edinburgh mathematician John Playfair was made in the context of his review of Pierre-Simon de Laplace's *Traité de méchanique céleste.*[174] Concerning British mathematicians capable of reading Laplace's treatise on astronomy, Playfair had claimed that "we shall not hardly exceed a dozen."[175]

Norton & Co., 1995), p. 413.

[173]George Biddell Airy, "Report on the Progress of Astronomy During the Present Century," *BAAS Report* (1832): 125-189 on p. 186.

[174]The first two volumes of *Méchanique céleste* were published in 1799, the next two in 1802 and 1805, and the fifth only in the 1820s. Ivor Grattan-Guinness explained that the first two volumes "more or less comprised a general theoretical basis for mathematical astronomy; the next two volumes... dealt with many of the details and special cases." In particular, the first volume was divided into two books "On the General Laws of Equilibrium and Motion," and "On the Law of Universal Gravitation, and the Motions of the Centres of Gravity of the Heavenly Bodies." Ivor Grattan-Guinness, *Convolutions in French Mathematics, 1800-1840*, 3 vols. (Basel, Boston, and Berlin: Birkhäuser, 1990) 1: 316-317. For more on Playfair's review, recall chapter 3.

[175]Playfair, "[Review:] *Traité de Méchanique Céleste*," *Edinburgh Review* 11 (1808): 249-284 on p. 281. John Toplis, like Playfair, had decried Britain's decline in mathematics. John Toplis, "On the Decline of Mathematical Studies, and the Sciences Dependent on Them," *Philosophical Magazine*

John Brinkley, the first Astronomer Royal of Ireland, was certainly among this dozen. The Senior Wrangler and First Smith's Prizeman for 1788, Brinkley was appointed to the Andrews Chair of Astronomy at Trinity College, Dublin in 1798. Although his observatory at TCD was ill-equipped until 1808,[176] Brinkley made astronomical advances by turning to theoretical research "within the frameworks established ... by Laplace."[177] Brinkley influenced the instruction of astronomy at his institution by authoring in 1808 *The Elements of Astronomy*, a textbook which remained a standard at TCD throughout the nineteenth century. He also acted as a mentor to William Rowan Hamilton, whom he met after the sixteen-year-old had discovered an error in one of Laplace's proofs in the *Méchanique céleste*. Hamilton would succeed Brinkley in the Andrews chair, and, though he devoted much of his energy to mathematics outside the realm of astronomy, Hamilton produced research on dynamics that, together with the work of Carl Gustav Jacobi, played an important role in the nineteenth-century development of the three-body problem.[178]

James Ivory also extended the astronomical frontiers established by French mathematicians. By the time he became Professor of Mathematics at the Royal Military

20 (1805): pp. 25-31. In 1814, he translated the first book of the *Méchanique céleste* into English. Alex D.D. Craik, "Calculus and Analysis in Early 19th-Century Britain: The Work of William Wallace," *Historia Mathematica* 26 (1999): 239-267 on p. 240. Laplace's treatise was also used in an illustration by Dionysius Lardner concerning the improvement of mathematical education at Trinity College, Dublin under Bartholomew Lloyd: "the study of mathematics has leaped a chasm of a hundred years, and men who, according to the system pursued two years before the advancement of Dr. Lloyd to the professorship of mathematics [in 1812], would be employed in fathoming the mysteries of Decimal Fractions, are rather more respectably employed with the *Méchanique Céleste*." Dionysius Lardner (1820), quoted in McConnell, pp. 76-77.

[176]Spearman, "Mathematics," p. 203.

[177]Grattan-Guinness, "Mathematical Research and Instruction in Ireland," p. 16.

[178]C. Wilson, "The Three-Body Problem," in *Companion Encyclopedia*, 2: 1054-1061 on p. 1057. For more on Hamilton and Jacobi's early work in this area, see Michiyo Nakane and Craig G. Fraser, "The Early History of Hamilton-Jacobi Dynamics," to appear.

College, Marlow, Ivory seems to have been familiar with the astronomical work of Laplace and Lagrange. He continued his research in mathematical astronomy after he retired from the Military College in 1816 and "was one of very few British scientists of this period whose work was taken seriously by leading Continental scholars, including Lagrange, Poisson, Liouville, and Jacobi."[179]

A prolific contributor to astronomy and geodesy, Ivory, in particular, made several notable contributions to the *Philosophical Transactions of the Royal Society of London* regarding the attraction of spheroids as related to determining the figure of the earth and, in two cases, criticized Laplace's treatment of this area.[180] Airy came to Laplace's defense against Ivory; however, in his article, the newly elected Lucasian Professor of Mathematics at Cambridge brought to light "another defect in Laplace's reasoning."[181]

As Senior Wrangler and First Smith's Prizeman for 1823, Airy had come to astronomy and geodesy through the "mixed" mathematics of the Cambridge curriculum and remained a champion of applied mathematics at Cambridge even when he left

[179]Craik, "Calculus and Analysis," p. 242. Ivory retired because of bad health, and "recurrent mental instability made him quarrel with and become suspicious of most of London's scientific community." For Ivory's international quarrel with Poisson about the French mathematician's treatment of an integral concerning surface harmonics, recall chapter 6.

[180]James Ivory, "On the Attractions of Homogeneous Ellipsoids," *Philosophical Transactions of the Royal Society* 99 (1809): 345-372; "On the Grounds of the Method Which Laplace Has Given in the Second Chapter of the Third Book of His *Mécanique Céleste* for computing the Attractions of Spheroids of Every Description," *Philosophical Transactions of the Royal Society* 102 (1812): 1-45; "On the Attractions of an Extensive Class of Spheroids," *Philosophical Transactions of the Royal Society* 102 (1812): 46-82; and "On the Expansion in a Series of the Attraction of a Spheroid," *Philosophical Transactions of the Royal Society* 112 (1822): 99-112. These articles will be discussed in the case study that follows.

[181]Airy, "Report," p. 179. George Biddell Airy, "On the Figure of the Earth," *Philosophical Transactions of the Royal Society* 116 (1826): 548-578.

the University for the position of Astronomer Royal at Greenwich.[182] In addition, his 1826 *Mathematical Tracts on Physical Astronomy, the Figure of the Earth, Precession and Nutation, and the Calculus of Variations* became an established university textbook.[183]

While Airy's textbook provided generations of Cambridge students with guidance on astronomy and geodesy, his most fruitful instance of inspiring a University student came from his 1832 report on the field of astronomy since 1800 for the British Association for the Advancement of Science. In that report, Airy chided his countrymen for their lack of results in planetary theories, adding that "in the theory of the new planets and the periodical comets, we not only have done nothing, but we have scarcely known what others have done."[184] Specifically, he commented that "there are ... subjects (the theory of Uranus, for instance,) in which the existence of difficulties is known, but in which we have no clue to their explanation."[185] Nine years later, the Cambridge undergraduate, John Couch Adams, chanced upon Airy's "Report" in a bookstore and decided soon after to investigate upon his graduation the difficulties of Uranus's orbit and the possible existence of a disturbing planet.[186]

After graduating as Senior Wrangler and Second Smith's Prizeman and proceeding to a fellowship at St. John's College, Cambridge in 1843, Adams set about his

[182]Recall Airy's efforts respecting the Smith's Prizes examinations in the overview on mathematical physics and mechanics.
[183]Grattan-Guinness, "Mathematics and Mathematical Physics," p. 101; *DNB*, s.v. "Airy, George Biddell.".
[184]Airy, "Report," p. 184.
[185]*Ibid.*, p. 189.
[186]Robert W. Smith, "The Cambridge Network in Action: The Discovery of Neptune," *Isis* 80 (1989): 395-422 on p. 400.

self-appointed task; by September 1845, he had developed a confident prediction for the orbit of a new planet that would come to be known as Neptune. Adams developed innovative mathematical techniques to handle the new problem of inverse perturbations inherent in the irregularities of Uranus's motion. So novel, in fact, were these techniques, that Adams's results were initially viewed skeptically by Airy and his successor in the Plumian Chair of Astronomy, James Challis.[187] In the end, the Cambridge group was narrowly beaten to the actual observational discovery of Neptune by two Berlin astronomers, Heinrich d'Arrest and J.G. Galle, using the results of the French mathematician, Urbain Le Verrier.[188] Adams had not published his results, and a heated priority dispute ensued, driven largely by nationalism and not the two mathematical astronomers. Adams and Le Verrier, in fact, were drawn into another debate at the end of the 1850s regarding the secular acceleration of the mean motion of the moon.[189] Despite the controversy, the discovery of Neptune was a victory for mathematical astronomy, and Adams, a tenant farmer's son, represented "an object lesson in armchair discovery: one might be too poor to afford a great telescope, but not to learn mathematics."[190]

The Tripos examination that Adams felt he must master before investigating the motion of Uranus reflected the reforms of William Whewell. Like Airy, Whewell was

[187] *Ibid.*, p. 399.

[188] For two discussions behind this near miss and the ensuing controversy, see Robert W. Smith, and Allan Chapman, "Private Research and Public Duty: George Biddell Airy and the Search for Neptune," *Journal for the History of Astronomy* 19 (1988): 121-139.

[189] For a discussion of this controversy, recall chapter 6.

[190] North, p. 430. For more on Adams, see H.M. Harrison, *Voyager in Time and Space: The Life of John Couch Adams* (Sussex, England: The Book Guild Ltd., 1994).

another defender of Cambridge "mixed" mathematics, and also made a number of contributions to astronomy and geodesy, in particular, to the theory of tides.[191] In the 1830s, he had successfully campaigned for the addition of continental planetary theory to the Mathematical Tripos, along with the topic of the figure of the earth, considered heterogeneously.[192]

During the subsequent contraction of Tripos subjects in the reforms of mid-century, the latter recent addition to the examination was limited to the case of the earth as a homogeneous body, and Laplace's coefficients were eliminated.[193] A sticking point in this decision, as reported by Stokes, a member of the Board of Mathematical Studies at Cambridge, was Clairaut's theorem. The theorem, which used the gravity at the equator and poles of the earth in order to determine its ellipiticity, was usually proven with Laplace's coefficients.[194] Stokes reported that relative to

[191]For example, William Whewell, "Essay towards a First Approximation to a Map of Cotidal Lines," *Philosophical Transactions of the Royal Society of London* 123 (1833): 147-236; "On the Empirical Laws of the Tides in the Port of London; With Some Reflexions on the Theory," *Philosophical Transactions of the Royal Society of London* 124 (1834): 15-45; "Researches on the Tides. Fourth Series. On the Empirical Laws of the Tides in the Port of Liverpool," *Philosophical Transactions of the Royal Society of London* 126 (1835): 1-16; and "Researches on the Tides. Fifth Series. On the Solar Inequality and on the Diurnal Inequality of the Tides at Liverpool," *Philosophical Transactions of the Royal Society of London* 126 (1836): 131-148; "Researches on the Tides. Twelfth Series. On the Laws of the Rise and Fall of the Sea's Surface during Each Tide," *Philosophical Transactions of the Royal Society of London* 130 (1840): 255-272. Unlike Airy, however, Whewell pursued this line of research with techniques developed from eighteenth-century theories and stayed away from the nineteenth-century continental innovations; his choice of techniques fits well with his dislike of the infusion of analytic methods into the Cambridge curriculum. Becher, p. 25.

[192]Becher, p. 23.

[193]Wilson, *Correspondence*, 1: 70. "If the co-ordinates of two points be (r, μ, ω) and (r', μ', ω'), and if $r' \nless r$, then the reciprocal of the distance between them can be expanded in powers of r/r', and the respective coefficients are Laplace's coefficients. Their utility arises from the fact that every function of the co-ordinates of a point on the sphere can be expanded in a series of them." W. W. Rouse Ball, *A Short Account of the History of Mathematics*, 3rd ed. (London: Macmillan and Co., 1901), p. 432.

[194]Todhunter gives Clairaut's theorem as "the sum of the ellipticity of the surface [of the earth considered heterogeneously] and Clairaut's fraction is equal to twice the ellipticity of the Earth

the figure of the earth considered heterogeneously, "some thought it a subject which did not at all repay for the trouble it took, but some were very strongly opposed to the rejection of Clairaut's Theorem. As to Laplace's Coefficients, no one I think wished to retain them if it were not for the figure of the Earth." Stokes then had a "happy thought" and proved Clairaut's Theorem "without any hypothesis as to the original fluidity of the Earth, or as to the constitution of its interior, provided we assume, as a matter of observation, that the surface is spheroidal, and $\perp$ to the direction of gravity."[195] Stokes's innovation rendered Laplace's coefficients superfluous, and Stokes wrote that "[t]hat being the case, I for my part think the Figure of the Earth is not worth reading, as a subject for examination here."[196] As a research mathematician on the curriculum development board, Stokes created a mathematical technique needed to streamline the Tripos.

One Cambridge student who passed the Tripos with flying colors after these reforms was George Darwin. Second Wrangler and Second Smith's Prizeman in 1868, Darwin, less than three decades later, "was considered Britain's leading geodesist."[197] Working in the tradition of physical geology explored by William Hopkins at Cam-

considered as a homogeneous fluid," where Clairaut's fraction is the "the value of gravity at the pole substract[ed by] the value of gravity at the equator, and divide[d by]... the value of gravity at the equator." Issac Todhunter, *History of the Theories of Attraction and the Figure of the Earth*, 2 vols. (London: Macmillan and Co., 1873) 1: 88.

[195]G.G. Stokes to William Thomson, Kelvin Papers, Cambridge University Library, 29 Mar. 1849, in Wilson, *Correspondence* 1: 69-70. Stokes published his result in G. G. Stokes, "On Attractions, and on Clairaut's Theorem," *Cambridge and Dublin Mathematical Journal* 4 (1849): 194-219; and "On the Variation of Gravity at the Surface of the Earth," *Transactions of the Cambridge Philosophical Society* 8(1849): 672-695. Recall chapter 4 for the reflection these publications gave on Stokes's view of the *Cambridge and Dublin Mathematical Journal*.

[196]Stokes to Thomson, 29 Mar. 1849, in Wilson, *Correspondence* 1: 69-70.

[197]David Kushner, "Sir George Darwin and a British School of Geophysics," *Osiris* 8 (1993): 196-224 on p. 205. George Darwin was the second son of Charles Darwin.

bridge in the 1830s and William Thomson in the 1860s,[198] Darwin employed mathematics to explore the earth's history in the universe.

For example, Darwin used a result stemming from the earlier controversy on the moon's mean motion to formulate a theory about the genesis of the moon. Recall from chapter six that Adams found that Laplace's generally accepted explanation of the secular acceleration in the mean motion of the moon in fact only accounted for around half of the phenomenon. In 1865, Charles Delaunay suggested that the slowing of the earth's rotation due to tidal friction represented the unrecognized cause of the discrepancy between theory and observation. With tidal friction, the moon's attraction on the oceans "acts like a friction brake on the earth's rotation, tending to slow it down. The reaction on the moon is to accelerate its motion linearly which causes it to recede."[199] With a system of differential equations and "tremendous mathematical insight into the process," Darwin traced this process back through time and theorized that the moon and earth were formed through the breakup of one primeval planet. This fission theory held sway for the next five decades, and is "one that still finds its proponents today."[200]

As Cambridge's Plumian Professor of Astronomy, Darwin transferred to his students ideas and approaches to mathematics that were "firmly rooted in the nineteenth-century Cambridge tradition of mixed mathematics" and that would come to be known as geophysics.[201] Many of these students made notable contributions to the

[198] *Ibid.*, pp. 197-198.
[199] *Ibid.*, p. 202-203.
[200] *Ibid.*, p. 204.
[201] Ibid., p. 211-212.

new field and were members of the nineteenth-century British mathematical publication community.[202]

Cambridge, as a bastion of "mixed" mathematics, played a prominent role in the careers of many of the nineteenth-century British mathematicians who pursued research in astronomy and geodesy. Yet, why did the share of mathematical articles in these areas drop during the nineteenth century, while those in the applied mathematical areas of mathematical physics and mechanics rose or stayed roughly constant? Why, for his evaluation of English astronomy for the years of 1800 to 1832, when publication activity in astronomy and geodesy was so high, did Airy conclude "[t]hat in those parts which depend principally on the assistance of governments or powerful bodies, requiring only method and judgement, with very little science, in the persons employed, we have done much; while in those which depend exclusively on individuals, we have done little. Secondly, that our principle progress has been made in the instrumental and mechanical parts, and in the lowest parts of Astronomy; while to the higher branches of the sciences we have not added anything"? [203]

These questions can be partly answered by the deaths of two men, James Ivory and John Brinkley, in 1842 and 1835, respectively. That their years of mathematical productivity coincide with those for which the percentage of astronomy and geodesy

[202]Of the "impressive list of astronomers and applied mathematicians... many of whom made important contributions to geophysics" listed by Kushner as Darwin's students, all except F.J.M. Stratton made mathematical contributions to nineteenth-century British scientific journals. These students were Alfred Barnard Basset, Arthur Berry, Ernest William Brown, George Hartley Bryan, Charles Chree, Phillip Herbert Cowell, Frank Watson Dyson, Sydney Samuel Hough, James Hopwood Jeans, Augustus Edward Hough Love, Ralph Allen Sampson, Herbert Hall Turner, Edmund Taylor Whittaker.

[203]Airy, "Report," p. 181.

in the mathematical articles of British scientific journals was greatest is not coincidental; in fact, their articles alone account for almost one-third of all the pages and almost one-fifth of the articles on astronomy and geodesy for 1800 to 1836. In particular, Ivory contributed ten extensive articles on these areas to the *Philosophical Transactions* and 27 articles to the *Philosophical Magazine*, and Brinkley made seven lengthy contributions on astronomy and geodesy to the *Transactions of the Royal Irish Academy.* In addition to Brinkley and Ivory, the Cambridge graduate and banker, John Lubbock, contributed over 13% of the pages and almost 8% of the articles on astronomy and geodesy for this period. While he continued to publish articles in these areas after 1836 (in fact, he participated in the moon's mean motion controversy in 1860, five years before his death), Lubbock's publication productivity in astronomy and geodesy dropped markedly after 1837. Similarly, Whewell largely left his research in mathematical astronomy and geodesy after 1837, when, as Master of Trinity College, Cambridge, he turned to other scientific and philosophical pursuits.[204] During the early nineteenth century, when most of the existing publication venues for mathematics were the transactions of scientific societies, which tended to publish lengthy articles, the activity of just a few people could radically change the composition of the mathematics found in British scientific journals.

Even without the extensive contributions of Brinkley, Ivory, and Lubbock, articles on geodesy and astronomy still accounted for a major portion of British mathemati-

[204]The mathematical pursuits of John Herschel, Senior Wrangler and First Smith's Prizeman for 1813, were also diverted to observational astronomy. For more on Herschel, see Günther Buttmann, *The Shadow of the Telescope: A Biography of John Herschel* (New York: Charles Scribner's Sons, 1970).

cal publications before 1837. In the climate surrounding the celebrated discoveries in observational astronomy by the sibling astronomers, William and Caroline Herschel, and continued by William's son John, understanding the heavens and the earth became a British point of honor and concern. The British government, not known for its scientific largesse, paid for the construction of an observatory at the Cape of Good Hope in 1828; Cambridge had established its observatory in 1824. Even if someone lacked access to these telescopes and other astronomical instruments necessary to becoming the next Herschel, with a mathematical education, especially one from Cambridge, one could aspire to become the next Laplace.

The number of articles published on geodesy and astronomy in the journals considered for tables 7B and 7C remained approximately the same for 1837 to 1867 and 1868 to 1900 as it had been for 1800 to 1836. While this constancy indicates that the areas still garnered interest from British mathematicians, the concomitant growth in articles published in other mathematical fields meant that the share of articles on geodesy and astronomy fell from over one-third before 1837 to less than one-tenth for our second period and to around one-twentieth for the third period. With the increased publication activity in mathematics, it would take more than a few prolific contributors like Ivory for astronomy and geodesy to achieve the large margins they had had earlier in the century.

Other factors might also have contributed to the dramatic drop in the proportion of geodesy and astronomy articles among mathematical publications. Perhaps the growing mathematical interest in phenomena such as heat, electricity, and magnetism diverted and divided the interests of British applied mathematicians who would have otherwise devoted themselves exclusively to investigations of the motions of the heavens and earth. Perhaps the excitement and concern over French astronomical advances at the turn of the century had cooled with time. Possibly, the remaining open mathematical questions germane to astronomy and geodesy seemed to many mathematicians resistant to solution with their available tools.

Although other mathematical fields occupied more and more room in this landscape after 1837, British mathematicians continued to make advances in astronomy and geodesy. The international controversy sparked by Adams alone indicates that astronomy was still a field linked to matters of national pride. George Darwin's successful extension and development of the questions and methods that would come to be known as geophysics indicates that the study of the heavens and earth remained a fertile — if not the most fertile — field of British mathematical research at the end of the century.

Case Study: Astronomy and Geodesy in the *Philosophical Transactions of the Royal Society of London*: 1800-1820

Until his death in 1820, Sir Joseph Banks served as President of the Royal Society, a position he had occupied since 1778. Banks was an irrepressible and ever-present force in the Society, and he collected a sizable group of detractors, many of whom were mathematicians. Olinthus Gregory, Professor of Mathematics at Woolwich, wrote in 1820 that Banks "had a great dislike of the mathematical sciences and did all in his power to suppress them; a natural consequence of which is, that mathematical knowledge has greatly depreciated in England during the last 40 years."[205] Banks, for his part, had commented during the 1780s that mathematics "is indeed little more than a tool with which other sciences are hewd into form."[206] In the Royal Society under Banks, "[w]here mathematical pursuits were encouraged they tended to be in areas of obvious application."[207]

While mathematics was clearly of secondary importance to Banks, he actively promoted and tried to control British astronomy. He successfully lobbied for William Herschel's position at the Royal Observatory at Kent in 1782 and hand-picked John Pond as Nevil Maskelyne's successor as the Astronomer Royal. He also advocated that the governorship of New South Wales go to Sir Thomas Brisbane in the hopes that Brisbane would build an observatory in the colony.[208] As a body, the Royal Society was closely involved with the Royal Observatory, whose reports the Society had published since 1767.[209] Astronomy, in fact, represented 17.25% of the papers printed in the *Philosophical Transactions* between 1781 and 1820.[210]

Where did mathematical astronomy and geodesy fall in the Royal Society's estimation during Banks's reign? As areas of mathematics with "obvious application"

[205]Olinthus Gregory to Heinrich Schumacher on the recently deceased Sir Joseph Banks, 27 June, 1820, quoted in Grattan-Guinness, "Mathematics and Mathematical Physics," p. 87. Gregory's removal from his position as Foreign Secretary of the Royal Society sparked a heated dispute between Banks and some mathematical members of the Royal Society in 1783 and 1784. See John Gascoigne, *Joseph Banks and the English Enlightenment: Useful Knowledge and Polite Culture* (Cambridge: University Press, 1994), pp. 259-260.

[206]Banks, quoted in Gascoigne, *English Enlightenment*, p. 255.

[207]Gascoigne, *English Enlightenment*, p. 254.

[208]John Gascoigne, *Science in the Service of Empire: Joseph Banks, the British State and the Uses of Science in the Age of Revolution* (Cambridge: University Press, 1998), pp. 29, 44, 194. With his own funds, Brisbane did build an observatory in New South Wales in 1822, which he subsequently donated to the British government. Airy, "Report," p. 130.

[209]Gascoigne, *Science in the Service of Empire*, p. 29.

[210]Gascoigne, *English Enlightenment*, p. 254.

to a field that Banks actively encouraged, they would seem to have been in a better position than pure mathematics; in fact, while papers covering several areas of mathematics appeared in the *Philosophical Transactions* for 1800 to 1820,[211] the only ones associated with the Royal Society's highest honor of the Copley Medal during this period were James Ivory's "various Mathematical communications printed in the Philosophical Transactions," communications concerned exclusively with mathematical astronomy and geodesy. While supportive, the *Philosophical Transactions* was an extremely limited venue for these areas; in fact, all of the mathematical astronomy and geodesy in the journal for these two decades came from only three men. This case study will consider the relationship of these men to the Royal Society in the order of appearance of their work as it examines the place of their articles in the *Philosophical Transactions.*

In 1799, John Hellins had been awarded the Copley Medal for a paper on "An Improved Solution of a Problem in Physical Astronomy; By Which Swiftly Converging Series are Obtained, Which are Useful in Computing the Perturbations of the Motions of the Earth, Mars, and Venus, by Their Mutual Attraction. To Which is Added an Appendix, Containing an Easy Method of Obtaining the Sums of Many Slowly Converging Series Which Arise in Taking the Fluents of Binomial Surds, &c."[212]

[211]Geodesy and astronomy accounted for 17% of the mathematical pages and eight out of the 47 articles in the *Philosophical Transactions* for 1800 to 1820. The page percentages and number of articles for the other mathematical areas are: Function Theory (17.0%, 7); Series (14.7%, 9); Mathematical Physics (12.9%, 4); Differential and Integral Equations (9.4%, 4); Combinations and Probability (7.7%, 2) Analytical Geometry (5.2%, 5); Number Theory (4.8%, 1); Pure, Elementary, and Synthetic Geometry (3.7%, 2); Algebra (3.8%, 2); Other (3.7%, 3).

[212]John Hellins, "An Improved Solution of a Problem in Physical Astronomy; By Which Swiftly Converging Series are Obtained, Which are Useful in Computing the Perturbations of the Motions of the Earth, Mars, and Venus, by Their Mutual Attraction. To Which is Added an Appendix,

Hellins was a self-educated schoolmaster, but, with the help of a local vicar, he became an assistant to Maskelyne at the Royal Observatory and was elected Fellow of the Royal Society in 1796.[213] Hellins supplemented his 1798 Copley-Medal-winning paper with an 1800 article that would be his last contribution to the *Philosophical Transactions* on astronomy.[214] His aims, as indicated by the longwinded titles of his papers, were the simplification of practical astronomical calculations, and his means drew from the Newtonian tradition of fluxions and fluents.

Abraham Robertson, the next nineteenth-century contributor to mathematical astronomy in the *Philosophical Transactions*, also consistently used the geometrical, Newtonian mathematical methods in his communications. Like Hellins, he came from humble origins but ended up as the Savilian Professor of Astronomy and Radcliffe Observer at Oxford and was elected Fellow of the Royal Society in 1795.[215] In 1806, Robertson communicated from Oxford an article investigating an error made by Newton regarding the precession of equinoxes.[216] While acknowledging Newton's mistake, Robertson was careful to add that the "deity"[217] of the Royal Society had applied

Containing an Easy Method of Obtaining the Sums of Many Slowly Converging Series Which Arise in Taking the Fluents of Binomial Surds, &c.," *Philosophical Transactions of the Royal Society of London* 88 (1798): 527-566.

[213]*DNB*, s.v. "Hellins, John."

[214]John Hellins, "A Second Appendix to the Improved Solution of a Problem in Physical Astronomy, Inserted in the Philosophical Transactions for the Year 1798, containing some further Remarks, and improved Formulæ for Computing the Coefficients A and B; by which the Arithmetical Work is Considerably Shortened and Facilitated," *Philosophical Transactions of the Royal Society of London* 90 (1800): 86-97.

[215]*DNB*, s.v. "Robertson, Abraham;" and Joseph Foster, *Alumni Oxonienses: The Members of the University of Oxford, 1715-1886: Their Parentage, Birthplace, and Year of Birth, with a Record of Their Degrees* (Oxford and London: Parker and Co., 1887-1888), s.v. "Robertson, Abraham."

[216]Abra[ha]m Robertson, "On the Precession of the Equinoxes," *Philosophical Transactions of the Royal Society of London* 97 (1807): 57-82.

[217]Gascoigne, *English Enlightenment*, p. 259.

his "transcendent abilities" to the problem.[218] He was less tactful in categorizing the attempts made by continental mathematicians at correcting the mistake "under three general heads... [first, those that] lead to a wrong conclusion, in consequence of a mistake committed in some part of the proceedings[,]... [second,] those in which the conclusions may be admitted as just, but rendered so by the counteraction of opposite errors[, and, third, those that]... are conducted without error fatal to the conclusion, and in which the result is as near the truth as the subject seems to admit."[219] Even attempts in the third category, in Robertson's opinion, suffered from "obscurity and perplexity."[220]

Robinson also tried to improve continental methods in astronomy in his 1816 *Philosophical Transactions* article on "Direct and Expeditious Methods of Calculating the Excentric from the Mean Anomaly of a Planet."[221] In his last *Philosophical Transactions* contribution on astronomy, however, he criticized one of his own countrymen. Robertson judged the formulas for finding the longitude and latitude of an object from its right ascension and declination and vice versa given by Nevil Maskelyne, the late Astronomer Royal, as containing two mistakes "which in certain cases would affect the accuracy of their application."[222] Like his treatment of Newton,

[218]Robertson, "Precession," p. 57.
[219]*Ibid.*, p. 58.
[220]*Ibid.*
[221]Abra[ha]m Robertson, "Direct and Expeditious Methods of Calculating the Excentric from the Mean Anomaly of a Planet," *Philosophical Transactions of the Royal Society of London* 106 (1816): 127-137.
[222]Abra[ha]m Robertson, "Demonstrations of the Late Dr. Maskelyne's Formulae for Finding the Longitude and Latitude of a Celestial Object from Its Right Ascension and Declination; And for Finding Its Right Ascension and Declination from Its Longitude and Latitude, the Obliquity of the Ecliptic Being Given in Both Cases," *Philosophical Transactions of the Royal Society of London* 106 (1816): 138-148 on p. 138.

Robertson chose his words carefully when criticizing a fellow, well-regarded member of the British astronomical establishment: "I trust I shall not be charged with any improper motive for thus noticing the mistakes. Candour, I hope, will view them only as accidental oversights, and the most sincere regard for his memory will allow the propriety of correcting them."[223]

James Ivory made his astronomical début in the *Philosophical Transactions* after Hellins and Robertson. Like Robertson, Ivory devoted many of his articles correcting what he thought were mistakes made by other mathematicians in their treatment of subjects in astronomy and geodesy. However, unlike Robertson or Hellins, Ivory used analytic techniques in this work that he had assimilated and developed from continental mathematicians. After studying at the University of St. Andrews and then the University of Edinburgh, where he received his MA in 1783, Ivory worked first as a schoolmaster and later as the manager of a flax-spinning company. He made all of his contributions to the *Philosophical Transactions* for the period considered here as Professor of Mathematics at the Royal Military College at Marlow (later Sandhurst) and before he was elected Fellow of the Royal Society in 1815.[224]

Ivory's first contribution to the *Philosophical Transactions*, published in 1809, concerned the attractions of spheroids.[225] In it, Ivory gave what Airy judged in 1832 as a "very beautiful theorem for finding the attraction of a spheroid generally, on a

[223] *Ibid.*, pp. 138-139.
[224] *DSB*, s.v. "Ivory, James."
[225] James Ivory, "On the Attraction of Homogeneous Ellipsoids," *Philosophical Transactions of the Royal Society of London* 99 (1809): 345-372.

point without it, from the attraction of a spheroid on a point within it." [226] Ivory wrote that he discovered his method for this problem related to the figure of the earth while studying Laplace's *Mechanique céleste.*[227] He delivered in his article the demonstration of what would become known as Ivory's Theorem, the combination of two results earlier considered by Laplace.[228]

While the result was not completely original, Ivory's method was hailed as a great simplification to the problem. For example, the French mathematician, Adrien-Marie Legendre, considered that "the analytic difficulties that this problem presents... thus disappear suddenly by the procedure of M. Yvory [sic], and a theory that belongs to the most abstruse analysis, can now be exposed in all of its generality and in a manner almost entirely elementary."[229] Ivory's discovery was all the more incredible in light of the following 1842 remark by the Royal Society President, the Marquis of Northampton. He speculated that in 1809 "probably not another person in the kingdom besides Mr. Ivory had read that part of Mécanique Céleste."[230] The novelty of the continental notation was shown by Ivory's use of the Newtonian terminology

[226] Airy, "Report," pp. 178-179.

[227] Ivory, "Attraction," p. 347.

[228] Todhunter, 2: 223. Ivory gives the theorem as follows: "If two ellipsoids of the same homogeneous matter have the same excentricities, and their principal sections in the same planes; the attractions which one of the ellipsoids exerts upon a point in the surface of the other, perpendicularly to the planes of the principal sections, will be to the attractions which the second ellipsoid exerts upon the corresponding point in the surface of the first, perpendicularly to the same planes, in the direct proportion of the surfaces, or areas, of the principal sections to which the attractions are perpendicular." Ivory, "Attraction," p. 355.

[229] Adrien-Marie Legendre, quoted in Todhunter, 2: 224. "Les difficultés d'analyse que présentait ce problême traité par tant de moyens différens, disparaissent ainsi toute d'un coup, par le procédé de M. Yvory, et une théorie qui appartenait à l'analyse la plus abstruse, peut maintenant être exposée dans toute sa généralité, d'une manière presque entièrement élémentaire." Translation mine.

[230] Marquis of Northampton, [Address Delivered Before the Royal Society], *Proceedings of the Royal Society of London* 4 (1837-1843): 399-460 on p. 410.

of fluents and fluxions to indicate his integral and derivative notation.[231]

In Ivory's next two contributions to the *Philosophical Transactions*, he again considered Laplace's treatment of the attraction of spheroids.[232] However, for these 1812 papers and another article in 1822,[233] Ivory chose to criticize rather than synthesize the French mathematician's reasoning.

In particular, Ivory protested the demonstration Laplace gave for "a certain equation relative to the potential of a nearly spherical homogeneous body at a point on its surface."[234] Ivory wrote that "I cannot grant that the demonstration which he has given of his proposition is conclusive. It is defective and erroneous, because a part of the analytical expression is omitted without examination, and rejected as evanescent in all cases... [As a result] the method for the attraction of spheroids, as it now stands in the *Méchanique Céleste*, being grounded on the theorem, is unsupported by any demonstrative proof."[235] In the last part of his paper, he used an article by Legendre from the *Journal de l'École polytechnique* for 1809 that had only months before arrived in London to try to buttress his case, even though Legendre did not dispute Laplace in his article.[236] Ivory had, in fact, failed to observe a limitation stated by

[231]See, for example, *ibid.*, p. 349.

[232]James Ivory, "On the Grounds of the Method Which Laplace Has Given in the Second Chapter of the Third Book of His *Mécanique Céleste* for computing the Attractions of Spheroids of Every Description," *Philosophical Transactions of the Royal Society* 102 (1812): 1-45; and "On the Attractions of an Extensive Class of Spheroids," *Philosophical Transactions of the Royal Society* 102 (1812): 46-82

[233]James Ivory, "On the Expansion in a Series of the Attraction of a Spheroid," *Philosophical Transactions of the Royal Society* 112 (1822): 99-112.

[234]Todhunter, 2: 253. The equation is "$\frac{1}{2}V + a\frac{dV}{dr} + \frac{2\pi a^2}{3} = 0$ ... [where] V is the potential at any point of the surface, r is the distance of that point from a fixed origin which is very near the center of gravity of the spheroid, a is the radius of a sphere which differs very little from the spheroid in volume."

[235]Ivory, "On the Grounds," p. 8.

[236]Todhunter, 2: 264.

Laplace that validated the use of this equation.[237] As the Marquis of Northampton tactfully explained in his obituary of Ivory, "Mr. Ivory has, with remarkable acuteness and analytical skill, exposed the defects of Laplace's investigation on *his* interpretation of the suppositions... we must [however] observe that the limitation expressed by Laplace... appears to be entirely overlooked by Mr. Ivory, and that this limitation, when its effects are fairly examined, completely removes the objection."[238] Despite the criticism Ivory directed towards Laplace's work, the French mathematician respected Ivory and "spoke in the highest terms of the manner in which he had treated his subject; one he said, of the greatest delicacy and difficulty, requiring no ordinary share of profound mathematical knowledge, and no common degree of industry and sagacity in the application of it." [239]

In referring to Ivory's Royal Medal for his work on atmospheric refraction in 1826, the then President of the Royal Society in 1833, the Duke of Sussex, described Ivory as "the first of our mathematicians who transplanted to this country the profound analytical science which LaGrange, Laplace, LeGendre, Gauss and others upon the Continent, had applied to the most important and sublime physical inquiries." Indeed, Ivory gained his place in the Royal Society and British mathematics not for his originality but for his ability to understand, simplify, and converse about astronomy and geodesy at an international level.[240]

---

[237] Laplace considered the approximating sphere to touch the spheroid; applied to the surface of the earth "it would exclude such irregularities as chasms or craters, and ridges or peaks, and mountains or valleys with vertical faces." Todhunter, 2: 261.

[238] Marquis of Northampton, p. 409.

[239] Humphry Davy, 1826, quoted in Marquis of Northampton, p. 409.

[240] Ivory performed such a simplification of known results in his last *Philosophical Transactions*

Ivory's contributions to the *Philosophical Transactions* before 1820 as well as those of Hellins and Robertson were made before the Royal Society had implemented its formal refereeing process.[241] Thus, the gates that let the articles of these three contributors into the Society's journals — and kept those of others out — may not have hinged strictly on content alone. While Hellins and Robertson were firmly ensconced within the British astronomical establishment of observatories and were established Fellows of the Royal Society, Ivory was Professor of Mathematics at a military college without affiliation to the Society. It is thus not surprising that the articles of Hellins and Robertson were given pride of place in the *Philosophical Transactions*; however, the fact that the Royal Society published many of Ivory's articles, and even awarded him the Copley Medal, indicates a real appreciation for his contributions. Ivory's theoretical work on astronomy and geodesy also had unexpected practical applications; it reflected well on the reputation of British science within the international scientific community, an application that Banks and the Royal Society recognized and appreciated.

An Overview of Algebra in Nineteenth-Century Britain

Although the applied mathematical subjects of mathematical physics, mechanics, astronomy, and geodesy captured the much of the attention of nineteenth-century British mathematicians, pure mathematics was by no means bullied out of the pages

article before 1820 (Marquis of Northampton, p. 410). James Ivory, "A New Method of Deducing a First Approximation to the Orbit of a Comet from Three Geocentric Observations," *Philosophical Transactions of the Royal Society of London* 104 (1814): 121-186. After 1820, Ivory made six more contributions to the *Philosophical Transactions* on astronomy and geodesy and won two Royal Medals.

[241]For more about this process, recall chapter 2.

of British scientific journals. In fact, the very pure mathematical subject of algebra occupied, on average, over 10% of the pages and articles in these journals. The development of this mathematical area throughout the century in Britain incorporated a variety of traditions, innovations, and viewpoints.

During the early nineteenth century, several British mathematicians tried to solidify the foundations of algebra in response to questions surrounding the validity of negative and imaginary numbers. These mathematical concepts, while extremely fruitful in algebra, were regarded as unsubstantiated and were loudly renounced at the turn of the century by Cambridge graduates, Francis Maseres and William Frend.[242] William Greenfield and John Playfair at the University of Edinburgh, Cambridge Fellow and Senior Wrangler, Robert Woodhouse, and Adrien-Quentin Buée, a French mathematician exiled in Britain, also recognized the problem of negatives and imaginaries; however, instead of excising them from algebra, and thus impairing the theory of equations, they looked for ways to justify their use.[243]

In trying to address the problem of negatives and imaginaries in his 1801 and 1802 contributions to the *Philosophical Transactions of the Royal Society of London* and his 1803 treatise on *The Principles of Analytical Calculation*, Robert Woodhouse, in particular, inspired the next generation of Cambridge mathematicians to conceive of algebra as having more generality and freedom than arithmetic.[244] *The Principles*

[242]Helena M. Pycior, "George Peacock and the British Origins of Symbolical Algebra," *Historia Mathematica* 8 (1981): 23-45 on pp. 27-28.
[243]*Ibid.*, pp. 29-30.
[244]Harvey W. Becher, "Woodhouse, Babbage, Peacock, and Modern Algebra," *Historia Mathematica* 7 (1980): 389-400 on pp. 392-393, 396. Robert Woodhouse, "On the Necessary Truth of Certain Conclusions Obtained by Means of Imaginary Expressions," *Philosophical Transactions of the Royal*

also provided an introduction to the Lagrangian, algebraic approach to the calculus for British mathematicians.[245] In fact, research in algebra and the calculus were often entwined in Britain during the early nineteenth century.

The Principles of Woodhouse, while ultimately influential, was at Cambridge "an unsuccessful calculus book."[246] However, Woodhouse's ideas about algebra and the calculus were developed by the short-lived Analytical Society of Cambridge and later disseminated by some of its former members.[247] In particular, George Peacock, who continued his academic career at Cambridge after his student days in the Analytical Society, extended Woodhouse's research on the foundations of algebra in his 1830 *Treatise on Algebra* and in his 1833 "Report on the Recent Progress and Present State of Certain Branches of Analysis" prepared for the British Association for the Advancement of Science.[248] In these works, Peacock developed his conception of "symbolical algebra," a system that agreed with arithmetic but extended beyond it to embrace negatives and imaginary numbers.[249]

Augustus De Morgan, Fourth Wrangler in 1827 and Professor of Mathematics at University College, London, continued this research on algebraic foundations in his

Society of London 91 (1801): 78-119; "On the Independence of Analytical and Geometrical Investigation and on the Advantages to be Derived from their Separation," *Philosophical Transactions of the Royal Society of London* 92 (1802): 85-125; and *The Principles of Analytical Calculuation* (Cambridge: University Press, 1803).

[245] Guicciardini, p. 129.

[246] Becher, "Woodhouse," p. 395.

[247] *Ibid.*, p. 395. For more on the Analytical Society and their publication, recall chapter 4.

[248] George Peacock, *Treatise on Algebra* (Cambridge: J. and J.J. Deighton, 1830); and "Report on the Recent Progress and Present State of Certain Branches of Analysis," *BAAS Report* (1833): 185-352. For more on Peacock's "Report," recall chapter 2.

[249] Helena M. Pycior, "George Peacock and the British Origins of Symbolical Algebra," *Historia Mathematica* 8 (1981): 23-45 on p. 34.

1837 text, *Elements of Algebra*, and in two articles published in 1839 and 1841 in the *Transactions of the Cambridge Philosophical Society.*[250] While he presented in these works the seemingly modern ideas of the commutativity and distributivity of addition and multiplication and the axioms of a field,[251] he felt that "[a]lgebra as an art," that is, algebra divorced from interpretation and solely reliant on formal rules "can be of no use to any one in the business of life."[252] In De Morgan's opinion, someone who puts a puzzle depicting the map of Europe "together by the backs of the pieces, and therefore is guided only by their forms, and not by their meanings, may be compared to one who makes the transformations of algebra by the defined laws of operation only; while one who looks at the fronts and converts his general knowledge of the countries painted on them into one of a more particular kind by help of the forms of the pieces, more resembles the investigator and the mathematician."[253] For Peacock and De Morgan, any worthwhile algebra could not completely be unfettered from interpretation.[254]

Like the troublesome negatives and imaginary numbers, the calculus of operations served as a catalyst for future British algebraic research. British mathematicians quickly accepted and extended the calculus of operations and produced an abundance

[250]Augustus De Morgan, *Elements of Algebra* (London: Taylor & Walton, 1837); "On the Foundations of Algebra," *Transactions of the Cambridge Philosophical Society* 7 (1839): 173-187; and "On the Foundations of Algebra, II," *Transactions of the Cambridge Philosophical Society* 7 (1841): 237-300. Interestingly, De Morgan's father-in-law was William Frend, the early nineteenth-century opponent of negatives and imaginaries.

[251]Joan L. Richards, "The Art and Science of British Algebra: A Study in the Perception of Mathematical Truth," *Historia Mathematica* 7 (1980): 343-365 on p. 354.

[252]Augustus De Morgan, 1837, quoted in *ibid.*, p. 354.

[253]Augustus De Morgan, 1841, quoted in *ibid.*, p. 356.

[254]Richards, "Art and Science," p. 356; and Pycior, "George Peacock," p. 37.

of articles on the differential and integral calculus that featured the method during the 1840s and 1850s.[255] This research led them "to the notion that it was not the nature of the objects under consideration which was most significant, but rather the laws of combination of their symbols."[256] In particular, Duncan Gregory, Fifth Wrangler of 1837 and editor of the *Cambridge Mathematical Journal*, explored these laws and inspired future algebraic research. Gregory's successor at the *Journal*, Robert Ellis, described fundamental issues of the method in an obituary of one of its greatest promoters, Gregory, who died in 1844 at the early age of 31:

> if the algebraical theorems by which these results [of the calculus of operations] were suggested, were true, *because* the symbols they involve represented quantities, and such operations as may be performed on quantities, then indeed the analogy would be altogether precarious. But if, as is really the case, these theorems are true, in virtue of certain fundamental laws of combination, which hold both for algebraical symbols, and for those peculiar to the higher branches of mathematics, then each algebraical theorem and its analogue constitute, in fact, only one and the same theorem, except quoad their distinctive interpretations, and therefore a demonstration of either is in reality a demonstration of both.[257]

Gregory published many articles on the calculus of operations in his *Journal* and, in so doing, encouraged his contributors to follow suit. In describing the *Cambridge Mathematical Journal*, De Morgan remarked to John Herschel in 1845 that "[i]t is done by the younger men...It is full of very original communications. It is, as is natural in the doings of young mathematicians, very full of symbols."[258]

---

[255]Koppelman, p. 200. Recall the discussion of the calculus of operations and its role in British research on differential and integral calculus in the introduction of this chapter.
[256]*Ibid.*, p. 157.
[257]Robert Leslie Ellis, "Memoir of the Late D.F. Gregory, M.A., Fellow of Trinity College, Cambridge," *Cambridge Mathematical Journal* 4 (1844): 145-152 on pp. 147-148.
[258]Augustus De Morgan, quoted in Koppelman, p. 189.

Not only the *Journal*, but the Cambridge mathematical curriculum of the 1840s was "full of symbols." In 1844, pure mathematical questions formed the majority of the Tripos, and synthetic solutions were requested for around one-seventh of the problems.[259] Indeed, Cambridge had become so infected with the *mania analytica* that it spawned, as noted above, a curricular backlash headed by William Whewell; by mid-century, "mixed" mathematics and synthetic, rather than algebraic, methods regained territory at Cambridge.[260] By the time of these reforms, however, the earlier, more analytic environment of Cambridge had produced two of the greatest algebraists of the nineteenth century, Sylvester, Second Wrangler of 1837, and Cayley, Senior Wrangler of 1842. Cayley, in particular, would continue to campaign for pure mathematics at Cambridge for much of the remainder of the nineteenth century.[261]

Outside Cambridge, British mathematicians extended traditional algebraic conventions. In particular, several Trinity College, Dublin graduates developed algebras over complex numbers. William Rowan Hamilton, interested in the problem of imaginaries that had inspired so much foundational work on algebra in Britain, presented to the Royal Irish Academy in 1833 a representation of complex numbers as ordered pairs that obeyed definitions of addition and multiplication. After an ill-fated ten-year search for an analogous algebra of triples, Hamilton found that if he discarded commutativity and looked at quadruplets instead of triplets, he obtained an algebra

[259]Becher, "Whewell," pp. 22-23. A discussion of synthetic versus analytic approaches follows in the section on analytic geometry below.

[260]Babbage coined the phrase *mania analytica* in 1817. Becher, "Woodhouse," p. 398.

[261]Becher, "Whewell," pp. 22-23.

he called the quaternions.[262] With the quaternions, mathematicians had a concrete example of a non-commutative system. Hamilton's discovery was followed a year later by the creation of the octaves by his friend, John Graves, 1827 TCD graduate and Professor of Jurisprudence at University College, London. Graves's algebra of dimension eight, as Hamilton subsequently showed, was not only noncommutative but also nonassociative.[263] Hamilton, who would devote the rest of his life to the promotion of quaternions, further extended this line of research in 1853 with biquaternions. Thomas Kirkman, 1833 TCD graduate and country rector in Croft, also investigated a class of these so-called hypercomplex numbers, which he termed pluquaternions. Kirkman discussed his ideas about pluquaternions with Cayley, who, as Kirkman reported in the *Philosophical Magazine*, gave him a "pregnant hint" about their multiplication.[264] As Cayley's role in Kirkman's work indicates, interest in hypercomplex systems was not limited to the graduates of TCD. Cayley, in fact, was the first to write about the quaternions after Hamilton and had independently discovered Graves's octaves, now known as Cayley numbers, in 1845.[265] James Cockle, an 1842 Cambridge graduate and lawyer, fashioned during the 1840s yet another hypercomplex system that he called tessarines,[266] and in 1878, William Clifford, Second Wrangler in 1867,

[262]McConnell, pp. 83-84.

[263]Karen Hunger Parshall, "Joseph H.M. Wedderburn and the Structure Theory of Algebras," *Archive for History of Exact Sciences* 32 (1985): 223-349 on p. 229.

[264]Tony Crilly, "The Young Arthur Cayley," *Notes and Records of the Royal Society of London* 52(1998): 267-282 on p. 276. Thomas P. Kirkman, "On Pluquaterions, and Homoid Products of Sums of n Squares," *Philosophical Magazine* 33 (1848): 447-459, 494-509.

[265]Crilly, "The Young Arthur Cayley, p. 272; and Parshall, "Wedderburn," p. 229.

[266]Crilly, *Mathematician Laureate*, chapter 7, p. 8. Cockle "also devoted much of his energy to the solution to the quintic equation, not trusting for many years, the proof given by Abel that such a formulae of service for all quintic equations could not exist. . . [He] wrote over a hundred mathematical papers. . . [but] he never was at the forefront of mathematical research." *Ibid.*

formulated two more types of algebras of which the quaternions and complex numbers are special cases.[267] With this line of algebraic research, Hamilton and his British successors explored the limits of mathematical freedom that had been suggested by Peacock in the 1830s.[268]

While he made important contributions to hypercomplex systems, Cayley extended his algebraic interests to group theory. In a series of articles in 1854 and 1859 in the *Philosophical Magazine*, he used insights gained from the calculus of operations to extend the group-theoretical work developing on the Continent.[269] In particular, he employed a group table to define the structure of a finite group and applied the notion of a group to quaternions, as well as the theories of equations, quadratic forms, and elliptic functions.[270] Cayley's correspondent, Kirkman, turned his attention to group theory in his attempt to win the 1860 Grand Prix of the Paris Académie des Sciences. While he did not win the prize, Kirkman did write an 1862 paper in the inaugural volume of the *Oxford, Cambridge, and Dublin Messenger of Mathematics* that was "probably the first systematic account in English of the elements of group theory."[271]

Although it represented a significant contribution to the abstraction of the concept of a group, Cayley's work on group theory accounted for only about 1% of his

[267]Walter Purkert and Hans Wussing, "Fundamental Concepts of Abstract Algebra," in *Companion Encyclopedia*, pp. 741-760 on p. 755.

[268]Pycior, "George Peacock," p. 41.

[269]Arthur Cayley, "On the Theory of Groups as Depending on the Symbolical Equation $\theta^n = 1$," *Philosophical Magazine*, 4th ser., 7 (1854): 40-47; 7 (1854): 408-409; and 18 (1859): 34-37.

[270]Purkert and Wussing, p. 748; and Crilly, *Mathematician Laureate*, chapter 8, pp. 2-5.

[271]Biggs, pp. 106-108. Thomas P. Kirkman, "Hints on the Theory of Groups," *Oxford, Cambridge, and Dublin Messenger of Mathematics* 1 (1862): 58-68. For more on Kirkman's attempts to win the Grand Prix, recall chapter 2.

publications.[272] Group theory largely failed to captivate British mathematicians like the calculus of operations had done at mid-century. In fact, the first book-length treatise in English on groups, *The Theory of Groups*, appeared only in 1897. Its author, William Burnside, graduated as Second Wrangler and First Smith's Prizeman in 1875 and ten years later became Professor of Mathematics at the Royal Naval College in Greenwich, where he would spend the rest of his teaching life. By 1894, he had become interested in the theory of finite groups and contributed valuable articles to this area for the next two decades.[273]

In 1854, 43 years before Burnside's treatise, Cayley had also briefly referred to the example of matrices in his work on group theory. By 1858, in the *Philosophical Transactions of the Royal Society of London*, he had turned his attention exclusively to matrices and more fully developed his ideas concerning them.[274] Initially referred to as a tableau by Cauchy, Gauss, and Eisenstein, the rectangular array was dubbed a matrix by Sylvester in an 1850 *Philosophical Magazine* article, where he considered this array within the theory of forms.[275] Again drawing on his experience with the calculus of operations, Cayley in 1858 developed a novel conception of matrices "as part of a mathematical system as distinct from being a lifeless notational device

[272]Crilly, *Mathematician Laureate*, chapter 8, pp. 2, 4. Cayley did return to group theory in 1878 when he identified all groups with substitution groups. This result later became known as Cayley's Theorem. Recall chapter 6.

[273]*DNB*, s.v. "Burnside, William;" and DSB, s.v. "Burnside, William."

[274]Arthur Cayley, "A Memoir on the Theory of Matrices," *Philosophical Transactions of the Royal Society of London* 148 (1858): 17-37.

[275]Ivor Grattan-Guinness and W. Ledermann, "Matrix Theory," in *Companion Encyclopedia*, pp. 775-786 on pp. 777-778; and James Joseph Sylvester, "On a New Class of Theorems in Elimination between Quadratic Functions," *Philosophical Magazine*, 3rd ser., 37 (1850): 363-370; or *The Collected Mathematical Papers of James Joseph Sylvester*, 4 vols. (Cambridge: University Press, 1904-1912; reprint ed., New York: Chelsea Publishing Co., 1973), 1: 145-150.

for algebraic forms."[276] In his article, he represented matrices by a single letter and defined the concepts of matrix addition, multiplication, and scalar multiplication.[277] Moreover, he "dealt with many algebra-theoretic properties of matrices, such as the existence of zero divisors, the conditions for commutativity and skew commutativity, and the properties of the transpose."[278] Cayley also stated but did not prove in general the Cayley-Hamilton Theorem, namely, that any square matrix satisfies its own characteristic equation.[279] In Tony Crilly's opinion, it was Cayley's experience with the calculus of operations, "where the substitution of operators for scalars was commonplace," that led him to the idea of substituting a matrix for the scalar of the characteristic polynomial.[280]

Like group theory, matrix theory received little attention in Britain after Cayley's 1858 memoir.[281] However, Sylvester breathed new life into the theory with his work on matrix algebras between 1882 and 1884. At Johns Hopkins University for virtually all of this period of concentrated work on matrices, Sylvester found a new class of matrix algebras in his representation of the quaternions as matrices and devised a matrix algebra of dimension nine, which he dubbed the nonions.[282] He also looked

[276]Crilly, *Mathematician Laureate* chapter 9, p. 16.

[277]Thomas Hawkins, "Another Look at Cayley and the Theory of Matrices," *Archives internationales d'histoire des sciences* 26 (1977): 82-112 on p. 91.

[278]Parshall, "Wedderburn," p. 238.

[279]Cayley proved the theorem for 2×2 matrices, and indicated that he had checked the theorem for 3×3 matrices. Hamilton, while working on quaternions, independently proved the theorem for 4×4 matrices. A general proof of the theorem was finally given by Georg Frobenius in 1878 and simplified by Arthur Buchheim in 1884. Hawkins, p. 93.

[280]Crilly, *Mathematician Laureate*, chapter 9, p. 18.

[281]Hawkins, p. 82. Hawkins states that "Clifford appears to be the sole British mathematician to pursue the ideas of Cayley's memoir before Sylvester's writing called attention to it." *Ibid.*, p. 103.

[282]Karen Hunger Parshall, "The Mathematical Legacy of James Joseph Sylvester," *Nieuw Archief voor Wiskunde*, 4th ser., 17 (1999): 247-267 on p. 263.

at minimum and characteristic polynomials, producing research that proved to be "very useful in analyzing the internal structure of algebras."[283] Furthermore, since Sylvester published much of this work in the *Comptes rendus* of the Paris Académie des Sciences, his approach to algebra was noticed by European mathematicians, notably Henri Poincaré; this continental connection "marked the first step toward a unification of the various approaches to the theory of algebras."[284]

While they produced valuable contributions to the theory of matrices, Sylvester and Cayley devoted most of their mathematical energy to the study of invariant theory. This field of research emerged on the pages of the *Cambridge and Dublin Mathematical Journal* in the 1840s and engaged a variety of British mathematicians throughout the nineteenth century. In fact, this area, along with that of quaternions, has been considered by Tony Crilly as one of "the two most intensively studied algebraic subjects in Britain during the second half of the century."[285] The case study below focuses on the development of this line of algebraic inquiry in Britain.

Although Cambridge was a major center for applied mathematics throughout the nineteenth century, many of the most profound British investigations in algebra during this period came from Cambridge-trained mathematicians. Recall from the overview of mathematical physics and mechanics above William Thomson's lament of 1864 "That the CAYLEYS would devote what skill they have to such things instead of to pieces of algebra which possibly interest four people in the world .... It is really too

[283]Parshall, "Wedderburn," p. 242.
[284]*Ibid.*, p. 243.
[285]Crilly, "The Young Arthur Cayley," p. 272.

bad that they don't take their part in the advancement of the world."[286] As noted, the analytical additions to the Tripos stemming from the work of the former members of the Analytical Society undoubtedly contributed to the algebraic tastes of a generation of Cambridge students. Interestingly, the volume of British mathematical articles on algebraic subjects, as measured here, reached its peak from 1837 to 1867, while the Cambridge graduates educated after these additions, but before the Tripos reforms of the 1850s, were in their prime.

As should now be clear, algebraic research in nineteenth-century Britain followed many intertwined paths. In their work on the foundations of algebra, the calculus of operations, hypercomplex number systems, group theory, matrix theory, and invariant theory, British mathematicians began to recognize a freedom in algebra that was unimaginable in the days of Maseres and Frend. Through a variety of journals, they communicated ever expanding results. Clearly, more than "four people" in Britain were interested in the "pieces of algebra" that regularly flew from Cayley's pen.

Case Study: Invariant Theory in Nineteenth-Century Britain through the Pages of Its Scientific Journals

The case of invariant theory represents an illuminating illustration of the role of nineteenth-century British mathematical journals in the communication of algebraic research.[287] Although they had been alluded to in the number-theoretic work of Carl

[286] William Thomson to Hermann Helmholtz, 31 July 1864, quoted in Smith and Wise, p.189.

[287] The following discussion of the contours of invariant theory in nineteenth-century Britain follows those of Karen Hunger Parshall, "Toward a History of Nineteenth-Century Invariant Theory," in *The History of Modern Mathematics*, ed. David E. Rowe and John McCleary, 2 vols. (Boston: Academic Press, 1989), 1: 157-206; and Tony Crilly, "The Rise of Cayley's Invariant Theory (1841-1862)," *Historia Mathematica* 13 (1986): 241-254; "The Decline of Cayley's Invariant Theory (1863-1895)," *Historia Mathematica* 15 (1988): 332-347.

Friedrich Gauss and the researches on mechanics of Joseph-Louis Lagrange, the ideas that came to characterize invariant theory were first presented by George Boole in the *Cambridge Mathematical Journal* in 1841.[288]

Given a binary quadratic form $Q(x,y) = ax^2+2bxy+cy^2$, Boole used a nonsingular linear transformation

$$\begin{aligned} x &\rightarrow mx' + ny' \\ y &\rightarrow m'x' + n'y' \ , \qquad mn' - m'n \neq 0 \end{aligned}$$

to transform $Q(x,y)$ into a new binary quadratic form $R(x',y') = \alpha x'^2+2\beta x'y'+\gamma y'^2$, where

$$\begin{aligned} \alpha &= am^2 + 2bmm' + cm'^2, \\ \beta &= amn + bmn' + bm'n + cm'n' \ , \text{ and} \\ \gamma &= an^2 + 2bnn' + cn'^2. \end{aligned}$$

Boole stated that "[t]he functions $\theta(Q)$ and $\theta(R)$," functions he obtained through a process of eliminating the variables in Q and R, respectively, by means of partial differentiation "may be shewn to possess many remarkable properties."[289] For this example, he showed that $\theta(Q) = b^2 - ac$, $\theta(R) = \beta^2 - \alpha\gamma$, and, suggestively,

$$\theta(R) = (mn' - m'n)^2\theta(Q).$$

Thus, the discriminant represented a simple example of what would later be called an invariant, that is, a function in the coefficients of a homogeneous polynomial that remains unaltered (up to a power of the determinant) after linear transformation.[290]

---

[288] Parshall, "Toward a History," pp. 158-160. See George Boole, "Exposition of a General Theory of Linear Transformations," *Cambridge Mathematical Journal* 3 (1841-1843): 1-20.

[289] Boole, "Exposition," p. 18.

[290] *Ibid.*, pp. 18-19. Boole also showed that $\theta(Q)$ and $\theta(R)$ represent the discriminant of the cubic for the case of a binary cubic. The appropriately defined discriminant is an invariant of binary forms of arbitrary order.

The author of this pioneering paper is an exception among the domestic mathematical contributors to British scientific journals considered in chapter 5, who were usually university educated, most likely at Cambridge or possibly at Trinity College, Dublin. Boole was a self-taught teacher in Lincoln at the time he wrote his "Exposition" and acquired university ties only later in life.[291] As an outsider, Boole used the *Cambridge Mathematical Journal*, which was primarily a venue for Cambridge mathematicians, as a means to get his work noticed.[292]

Someone in Cambridge did, in fact, notice Boole's work. By 1844, the Cambridge graduate, Arthur Cayley, had read Boole's "Exposition" and began a lifelong relationship with what would come to be called invariant theory. He started corresponding with Boole and was soon publishing his own results also in the *Cambridge Mathematical Journal.*[293]

In an 1845 paper there, entitled "On the Theory of Linear Transformations," Cayley discovered a new invariant of a binary quartic, that is, a homogeneous polynomial of order four in two variables. [294] As new invariants were discovered, it soon became clear that algebraic relationships could exist between them. Analyzing and finding these relationships, later termed syzygies by Sylvester, would form a major and a particularly difficult problem for invariant theorists.[295]

In their work on invariants, Cayley and Sylvester also became interested in the

[291]In 1849, Boole became Professor of Mathematics at Queen's College Cork.
[292]For more on the *Cambridge Mathematical Journal* and its contributors, recall chapter 4.
[293]Crilly, "Rise," pp. 241-243.
[294]Arthur Cayley, "On the Theory of Linear Transformations," *Cambridge Mathematical Journal*: 4 (1845): 193-208.
[295]Parshall, *Life and Work*, p. 24.

more general concept of covariants. A covariant is a function in the coefficients *and* variables of the homogeneous polynomial with the invariance property of Boole's discriminants. Two goals developing at this time for the growing group of British mathematicians interested in invariant theory involved finding the minimal generating set of covariants for binary forms of given orders, known as the fundamental system of groundforms, and finding the syzygies among the elements in a fundamental system.[296]

The interest in solving these problems was not limited to Britain. Charles Hermite at the École Polytechnique actively worked in the area of invariant theory and contributed an important result to the *Cambridge and Dublin Mathematical Journal.* In "Sur la théorie des fonctions homogènes à deux indéterminées," his third article to the journal, Hermite presented his law of reciprocity for the first time.[297] This law states that the number of covariants of the pth degree in the coefficients (and any order in the variables) of a binary form of order m is equal to the number of covariants of the mth degree in the coefficients of a binary form of order p. Hermite's surprising result effectively cut the work of systematically determining the covariants and invariants for binary forms of each successive degree in half by doubling the number of known invariants and covariants.

As interest in invariant theory spread, Sylvester found himself in the position of judging the work of his colleagues. In April of 1855, he authored a report on the

[296]Parshall, "Toward a History," pp. 167-168.

[297]Charles Hermite, "Sur la théorie des fonctions homogènes à deux indéterminées," *Cambridge and Dublin Mathematical Journal* 9 (1854): 172-217.

invariant-theoretic work of William Spottiswoode. In his referee's report, Sylvester wrote that "[t]he memoir shows great industry and has some points of interest; [but] that it contributes materially to promote the existing state of knowledge of the subject in which it treats is open to question."[298] Sylvester suggested that it be abstracted in the Society's *Proceedings* and that Spottiswoode "defer publication of the memoir *in extenso* until he has been able to concentrate a greater amount of thought upon the subject and produced a result which shall do more ample justice to his powers as a discoverer."[299] Sylvester's suggestions were taken, and Spottiswoode's "Researches on the Theory of Invariants" appeared in abstracted form in the Society's *Proceedings* but never actually made it into the *Philosophical Transactions*.[300]

While he wanted to uphold the quality of the *Philosophical Transactions*, Sylvester was clearly uncomfortable in his role as referee, a job he called "thankless" and capable of "letting in the influences of fear of giving offence & favor."[301] With Spottiswoode's memoir, Sylvester had had enough: in the report, he expressed his "exceeding unwillingness to be again called upon to act in the capacity of referee upon papers submitted for insertion in the *Transactions*."[302]

Cayley was more successful than Spottiswoode in having his invariant-theoretic

[298] J.J. Sylvester to The Committee of Papers of the Royal Society, 26 April 1855, in Parshall, *Life and Work*, p. 85.
[299] *Ibid.*, p. 86.
[300] William Spottiswoode, "Researches on the Theory of Invariants," *Proceedings of the Royal Society of London* 7 (1854-1855): 204-207. Cayley also refereed and subsequently rejected Spottiswoode's paper for publication in the *Philosophical Transactions.* Parshall, *Life and Work*, p. 86.
[301] J.J. Sylvester to The Committee of Papers of the Royal Society, 26 April, 1855, in Parshall, *Life and Work*, p. 86. For more on the mathematical referees of the Royal Society of London, recall chapter 2.
[302] *Ibid.*

work please the referees for the Royal Society's *Philosophical Transactions.* In a series of ten "Memoirs on Quantics," spanning two decades, Cayley used the ample room of the Society's flagship journal to lay out the foundations, accomplishments, questions, and connections of his approach to invariant theory.[303] In his "Second Memoir upon Quantics," appearing in 1856, Cayley presented a theorem that provided a huge boost for finding and counting covariants.[304]

Using partial differentials as operators that "annihilated" terms, Cayley provided a procedure for detecting covariants and provided an algorithm that theoretically generated all covariants. Given the binary quantic of order m in the variables, $(a, b, \ldots b', a')$ $(x, y)^m$,[305] Cayley let

$$\begin{aligned} a\partial_b + 2b\partial_c \ldots + mb'\partial_{a'} &= X \text{ and} \\ mb\partial_a + (m-1)c\partial_b \ldots + a'\partial_{b'} &= Y \end{aligned}$$

and noted that "any function which is reduced to zero by each of the operations $X - y\partial_x$, $Y - x\partial_y$ is a covariant of the quantic."[306]

He then considered A, the most general function possible in the coefficients of the quantic, such that A has degree θ and weight $\frac{1}{2}(m\theta - \mu)$.[307] If $XA = 0$, and if new coefficients $B, C, \ldots B', A'$ are defined recursively as

[303]Crilly, "Rise," p. 246.

[304]Arthur Cayley, "Second Memoir upon Quantics," *Philosophical Transactions of the Royal Society of London* 146 (1856): 101-126.

[305]Cayley used the linked brackets, $\between$ to indicated that the coefficients of the binary quantic in question would include the binomial coefficients. In modern notation, $(a, b, \ldots b', a' \between x, y)^m$ would be written as $\binom{m}{0}ax^m + \binom{m}{1}bx^{m-1}y + \ldots + \binom{m}{m-1}b'xy^{m-1} + \binom{m}{m}a'y^m$ Linked brackets with an arrow, $\between$, indicate the suppression of these binary coefficients. Crilly, "Rise," p. 251.

[306]Cayley, "Second Memoir," p. 104.

[307]Here, the degree is the degree of homogeneity in the coefficients, the *weight* assigns a numerical value to a monomial in the coefficients and in the variables x and y, and μ denotes the order or the degree of homogeneity in the variables x and y.

$$B = YA \qquad C = \tfrac{1}{2}YB, \ldots A' = \tfrac{1}{\mu}YB',$$

"then will $(A, B, \ldots B', A' \between x, y)^{\mu}$," that is, the quantic of order μ in the variables with these new coefficients, "be a covariant."[308] From these results, Cayley also deduced in his "Second Memoir" a formula for finding the number of asyzygetic, that is, linearly independent, covariants of order μ and degree θ for a given binary quantic as "the number of terms of the degree θ and weight $\frac{1}{2}(m\theta - \mu)$, less the number of terms of the degree θ and weight $\frac{1}{2}(m\theta - \mu) - 1$."[309]

The argument behind Cayley's formula hinged on an assumption of linear independence that he was "morally" certain of, but that was not actually proved until over two decades later by Sylvester. In the heat of the battle of actually *finding* invariants, Cayley and Sylvester had glossed over what would come to be recognized as key theoretical underpinnings of their theory. While Cayley's moral certainty proved true for this example, in another part of his "Second Memoir," Cayley, as Karen Parshall has pointed out, "was not so lucky. Again, an assumption about this linear independence, this time a false assumption, led him badly astray."[310]

This assumption of linear independence led Cayley to believe that the number of irreducible covariants for the binary quintic was infinite. However, this assertion

[308]Cayley, "Second Memoir," p. 107.

[309]*Ibid.* In his 1895 account of this formula in his textbook, *An Introduction to the Algebra of Quantics*, Edwin Elliott presents this formula as

$$(\tfrac{1}{2}(m\theta - \mu); \theta, \mu) - (\tfrac{1}{2}(m\theta - \mu) - 1; \theta, \mu),$$

where $(w; d, r)$ denotes the number of ways of getting w by adding d numbers from the set $\{0, 1, 2, \ldots, r\}$ with repetition allowed. Edwin Bailey Elliott, *An Introduction to the Algebra of Quantics*, 2nd ed., (Oxford: University Press, 1913; reprint ed., Bronx, NY: Chelsea Publishing Co., 1964), pp. 119, 147-148.

[310]Parshall, "Toward a History," p. 169.

did not stop the British invariant-theorists from continuing to calculate covariants for these orders as Cayley had done in the "Second Memoir" for the binary quintic. As Tony Crilly has described, these mathematicians identified and classified covariants in the spirit of Victorian collectors cataloging flora and fauna, and they doggedly continued a project that Cayley's finding showed was impossible to finish.[311]

In an 1859 review in the *Philosophical Magazine* of *Lessons Introductory to the Modern Higher Algebra*, a text on invariant theory by the Dublin mathematician, George Salmon, the writer marveled at and slightly mocked the new mathematical creatures of the theory; he also gave a account of invariant theory's growing appeal:

> Within the last eighteen years the old and well-trodden field of Algebra has been invaded by a host of new and strange intruders, with the odd sounding names of 'Determinants,' 'Hyperdeterminants,' 'Discriminants,' 'Emanants,' 'Invariants,' 'Evectants,' 'Bezouthiants,' 'Hessians' (having no connection, however, with either 'Boots' or 'Crucibles'), 'Canonizants' (of no religion), 'Dialytics,' and 'Quantics.' Many a reader of the Cambridge Mathematical Journal, the Philosophical Magazine, Philosophical Transactions &c, has wondered what it all meant — wondered sometimes, indeed, whether there was *any meaning at all* in these new expressions and symbols. Very few even of the best mathematicians of the day have paid much attention to the subject as yet; but they are beginning to do so, finding that there is really something like a new branch growing out of their old tree — nay, more, that the young off-shoot is already bearing fruit.[312]

Collecting the mathematical specimens of invariant theory was no mean feat in an age where a "computer" designated a human being and not a machine. An 1855 article by the Italian invariant-theorist, Francesco Faà de Bruno, gives a sense of the

[311] Crilly, "Rise," p. 249.

[312] Anonymous, "The Rev. G. Salmon's *Lessons Introductory to the Modern Higher Algebra*," *Philosophical Magazine*, 4th ser., 18 (1859): 67-68. Also quoted in Rod Gow, "George Salmon 1819-1904: His Mathematical Work and Influence," *Irish Mathematical Society Bulletin* no. 39 (1997): 26-76 on p. 58.

laborious calculations inherent in the mission of finding invariants and covariants. Faà de Bruno was a student in Paris when he submitted his calculation of the "Invariant of the Twelfth Degree of the Quintic $(a, b, c, d, e)(x, y)^5$" to the newly founded *Quarterly Journal of Pure and Applied Mathematics.*[313] Besides a short introductory paragraph, the remainder of the three-page article is just a listing of part of "the general expression for the invariants of the twelfth degree of the quintic $(a, b, c, d, e)(x, y)^5$," a listing with 228 entries.[314]

The load of invariant hunters like Faà de Bruno was considerably lightened in 1868 by a landmark finding that the German Paul Gordan published in Crelle's *Journal.*[315] Using the symbolic techniques developed by the largely parallel German school of invariant-theorists, Gordan found that the number of irreducible, that is, algebraically independent, covariants for all binary quantics was finite.[316] While this development reduced the British objective of finding covariants to more human proportions, it meant that Cayley's assumption had been wrong, and theoretically, the British school had a lot of catching up to do. For example, a proof of Gordan's theorem was needed to put the British approach on an equal theoretical footing with that of the Germans. Despite numerous attempts by Sylvester and Cayley, however, this proof never materialized.[317]

---

[313]Francesco Faà de Bruno, "Invariant of the Twelfth Degree of the Quintic $(a, b, c, d, e)(x, y)^5$," *Quarterly Journal of Pure and Applied Mathematics* 4 (1855): 361-363.

[314]*Ibid.*, p. 361. For more on the international contributions to the *Quarterly Journal of Pure and Applied Mathematics,* recall chapter 6.

[315]Paul Gordan, "Beweiss, dass jede Covariante und Invariante einer binaeren Form eine ganze Function mit numerische Coefficienten einer endlichen Anzahl solchen Formen ist," *Journal für die reine und angewandte Mathematik* 69 (1868): 323-354.

[316]Parshall, "Toward a History," p. 179.

[317]*Ibid.*, p. 180, 185.

Cayley had initially introduced Germany to his invariant-theoretic ideas in a contribution (his first) to Crelle's *Journal für die reine und angewandte Mathematik* in 1845.[318] He was one of the first British contributors to the journal, which was established in 1826 by August Leopold Crelle, and Cayley continued to publish there throughout his life. As noted in chapter 6 above, Cayley introduced in the *Journal* a method for calculating invariants that involved the so-called hyperdeterminant derivative, a method that Cayley himself did not pursue but that was developed by German mathematicians.[319] The German school also adopted Sylvester's terms of invariant and covariant, which Cayley introduced in an 1851 contribution to Crelle's *Journal*.[320] Interestingly, Cayley continued publishing invariant-theoretic articles in Crelle's *Journal* as well as in the *Mathematische Annalen* well after the British and German methods had diverged to a level of almost mutual unintelligibility.[321] These articles in invariant theory underline Cayley's general commitment to publishing in international journals.[322]

The news of Gordan's 1868 result seemed to set back the British approach to invariant theory on the international stage. The German symbolic system allowed its

[318]Arthur Cayley, "Note sur deux formules données par MM. Eisenstein et Hesse," *Journal für die reine und angewandte Mathematik* 29 (1845): 54-57.

[319]Crilly, "Rise," p. 245. Recall chapter 6.

[320]Arthur Cayley, "Note sur la théorie des hyperdéterminants," *Journal für die reine und angewandte Mathematik* 42 (1851): 368-371.

[321]Cayley started publishing in English in Crelle's *Journal* in 1876. His last *Mathematische Annalen* paper was a faulty proof of Gordan's Theorem. Arthur Cayley, "On the Finite Number of the Covariants of a Binary Quantic," *Mathematische Annalen* 34 (1889): 319-320. For more on this erroneous proof, see Crilly, *Mathematician Laureate*, chapter 16, pp. 22-25. For an indication of the conceptual disconnect that emerged between the German and British schools, see Paul Gordan to J.J. Sylvester, 6 October, 1878, in Parshall, *Life and Work*, p. 193.

[322]For more on Cayley's contributions to foreign journals, recall chapter 6.

users to work, in some sense, just above the level of actual calculation; this higher level of abstraction helped Gordan achieve his result.[323] However, for explicitly calculating covariants, the British system was the more effective, but still arduous, alternative. The possibility for nationalistic tension between the two camps of invariant theorists can be seen the the 1876 remarks of Sylvester to Spottiswoode:

> Those piratical Germans Clebsch and Gordan who have so unscrupulously done their best to rob us English of all the credit belonging to the discoveries made in the New Algebra [i.e., invariant theory] will now suffer it is to be hoped the due Nemesis of their misdeeds. Nothing in Clebsch and Gordan is *really* new but their Cumbrous method of *limiting* (not *determining*) the Invariants to any given form. This part of their work is now I think destined to be blotted out of existence.[324]

Two years after Sylvester's letter, Sylvester and Cayley appealed to the British Association for the Advancement of Science for a grant to employ human computers to help them do what the British approach did best: determining, rather than limiting, invariants.[325] This grant allowed Sylvester, at the Johns Hopkins University at that time, to pay his American student, Fabian Franklin, to assist him in completing the tables of irreducible covariants in a fundamental system for binary quantics up to order 10. These results were printed in the *American Journal of Mathematics*, the journal founded and edited by Sylvester.[326] Thus, through the efforts of Britain's leading invariant-theorists, the British Association funded American research and

[323]Parshall, "Toward a History," p. 187.

[324]J.J. Sylvester to William Spottiswoode, 19 Nov. 1876, in Parshall, *Life and Work*, pp. 174-175.

[325]Crilly, "Decline," p. 338. "Report of the Committee, Consisting of Professor Sylvester, F.R.S., and Professor Cayley, F.R.S., Appointed for the Purpose of Calculating Tables of the Fundamental Invariants of Algebraic Forms," *BAAS Report* (1879): 66.

[326]James Joseph Sylvester, "On the Complete System of the 'Grundformen' of the Binary Quantic of the Ninth Order," *American Journal of Mathematics* 2 (1879): 98-99; and "Tables of the Generating Functions and Groundforms for the Binary Quantics of the First Ten Orders," *American Journal of Mathematics* 2 (1879): 223-251.

provided material for a new American mathematical journal.

Sylvester and Franklin were aided in their hunt for covariants by Sylvester's so-called Fundamental Postulate. Like some of the other tools used by the British invariant theorists, this technique had worked for every case to which it had been applied, but it had not been proven rigorously.[327] In the words of fellow British invariant-theorist, Edwin Bailey Elliott, the postulate allowed "the labour of discovery [to be]...reduced to tractable dimensions."[328]

The Fundamental Postulate assured invariant hunters that there could not exist a syzygy, that is, an algebraic relationship among covariants, and an irreducible covariant of the same order and degree.[329] This principle, used in tandem with what Sylvester called the method of *tamisage* or winnowing, assured Sylvester that there were no irreducible covariants of degree five and order 13 in his step-by-step search for the fundamental system of groundforms of the binary septimic.

Recall that Cayley's formula from his "Second Memoir" of 1856 says for this case that the number of asyzygetic covariants of this degree and order is [330]

$$(11; 5, 13) - (10; 5, 13) = 4.$$

The tamisage process used generating functions to seek out irreducible covariants. For our example here, Sylvester's generating functions told him that there were four composite covariants of degree five and order 13. His fundamental postulate told him at that point to stop looking for irreducible covariants of this degree and order:

[327] Crilly, "Decline," p. 338.
[328] Elliott, *Introduction*, p. 174.
[329] *Ibid.*, p. 174.
[330] This difference can be found by looking at an appropriate generating function. See Elliott, *Introduction*, pp. 173-179.

if there were such a covariant, then his four composite covariants must not all be linearly independent, thanks to Cayley's theorem. If not linearly independent, two of the group must be connected by a linear relation, which would give a syzygy of order five and order 13. However, such a syzygy could not, by the fundamental postulate, coexist with an irreducible covariant of the same order and degree.[331]

Sylvester's method of tamisage, combined with the fundamental postulate, seemed to give the British a tangible advantage over the Germans in invariant theory;[332] this rival approach chronically *over*estimated the number of irreducible invariants, whereas Sylvester's approach avoided this problem. However, in an 1877 letter to Cayley, Sylvester suggested that their method might be susceptible to another kind of weakness:

> I think I may now announce with moral certainty that my method [of tamisage] completely solves the problem of finding the *grundformen* for binary forms and systems of binary forms... in all cases — I have sent an account of the method to the Comptes rendus — I might to add that *anterior to all* verification this method *could not* give superfluous forms — but it is metaphysically conceivable that it might give *too few* grundformen.[333]

Publication in foreign journals was clearly essential for Sylvester's quest to make his results well known.[334] However, this result involved the "moral certainty" that had often come into play in the British approach to invariant theory. Unfortunately for Sylvester, moral certainty was not enough in this instance.

[331]For more on this example, see Parshall, *Life and Work*, p. 178. For a discussion of tamisage, see Elliott, *Introduction*, pp. 173-179, and Crilly, "Decline," pp. 338-340.

[332]Crilly, "Decline," p. 337.

[333]J.J. Sylvester to Arthur Cayley, 23 April, 1877 (his emphasis), in Parshall, *Life and Work*, p. 177.

[334]For more on Sylvester's efforts to maintain an international reputation, see Karen Hunger Parshall and Eugene Seneta, "Building an International Reputation: The Case of J.J. Sylvester (1814-1897)," *American Mathematical Monthly* 104 (1997): 210-222.

In the 1882 volume of the *American Journal of Mathematics*, Sylvester proved that his Fundamental Postulate did not always hold, and soon after, the English mathematician, James Hammond, provided a concrete counterexample to the postulate in the *Proceedings of the London Mathematical Society*.[335] There, Hammond presented both a linear relationship among the four composite covariants that Sylvester had found and an irreducible covariant of degree five and order 13.[336] Hammond had graduated 35th from Cambridge in 1874, but had then moved to London to live as a private scholar. For someone like Hammond doing research outside the academic environment, the London Mathematical Society provided a link to other mathematicians. Cayley published an addition to the paper, also in the *Proceedings*, where he cast Hammond's example in his own notation and emphasized the "extreme importance of Mr. Hammond's result, as regards the entire subject of covariants."[337]

While the British approach to invariant theory allowed its adherents to produce massive tables of calculations, missteps such as Sylvester's Fundamental Postulate highlighted the weakness of its theoretical underpinning. Salmon's 1859 text, *Modern Higher Algebra*, had, in fact, been an attempt to rigorize the foundations of the British approach to invariant theory.[338] Edwin Elliott, an Oxford graduate, lecturer,

[335] James Joseph Sylvester, "On Subinvariants, That Is, Semi-Invariants to Binary Quantics of an Unlimited Order," *American Journal of Mathematics* 5 (1882): 79-136. Parshall, *Life and Work*, p. 178.

[336] James Hammond, "Note on an Exceptional Case in which the Fundamental Postulate of Professor Sylvester's Theory of Tamisage Fails," *Proceedings of the London Mathematical Society* 14 (1882): 82-88.

[337] Arthur Cayley, "Addition to the Foregoing Paper," *Proceedings of the London Mathematical Society* 14 (1882): 88-91 on p. 88.

[338] Parshall, "Toward a History," p. 186. George Salmon, *Lessons Introductory to the Modern Higher Algebra*, 5th ed. (Dublin: Hodges, Figgis & Co., 1885; reprint ed., Bronx, NY: Chelsea Publishing Co., 1964).

and later, Oxford's first Waynflete Professor of Pure Mathematics continued these efforts in his 1887 article published in the *Messenger of Mathematics*, where he more rigorously established the standard definition of an invariant.[339]

Elliott first gave the definition that "[a]ny function of the coefficients is called an invariant, if, when the quadric is linearly transformed, the same function of the new coefficients is equal to the old function *multiplied by some power of the modulus*," or the determinant, "*of transformation*."[340] Elliott then suggested that instead of "some power of the modulus," the definition should give the less stringent requirement of "some factor depending only on the coefficients in the scheme of transformation."[341] The remainder of Elliott's paper concerned proving that this factor must, in fact, be a power of the determinant. Elliott believed that presenting a more general definition of the invariant, then proving as a theorem that the more restrictive traditional definition must hold, should be included in any introduction to invariant theory "so that full rigour might be at once given to certain indirect processes of investigation."[342]

The *Messenger of Mathematics* was a good fit for Elliott's article, which tried to clarify the introduction to invariant theory. Through the *Messenger*, Elliott's article came before those embarking on mathematical research.[343] In 1895, the recently appointed Professor Elliott would expand his mission of bringing rigor to invariant theory by writing *An Introduction to the Algebra of Quantics*. This work, which

[339]Edwin Bailey Elliott, "On the Definition of an Invariant," *Messenger of Mathematics* 16 (1887): 5-8.

[340]Elliott, "Definition," p. 5.

[341]*Ibid.*

[342]*Ibid.*

[343]For more on the young researchers who published in the *Messenger*, recall chapter 4.

was reissued in 1913, was long recognized as the definitive textbook on the British approach to invariant theory, organizing as it did the product of over 50 years of British journal articles on the subject.

As this case study suggests, what began as an unassuming article in the 1841 *Cambridge Mathematical Journal*, blossomed into a new field of research that an international collection of mathematicians actively pursued throughout the rest of the nineteenth century. By and large, this development, including its innovations, missteps, and corrections, played on the stage of scientific journals. Clearly, these mathematicians used different journals for different purposes: Cayley's long "Memoirs on Quantics" exceeded the bounds of the *Messenger*, just as Elliott's short "Definition of an Invariant" was not weighty enough for the *Philosophical Transactions*. Within the widening spectrum of publication options for mathematical articles, the British invariant-theorists developed techniques that later, while no longer applied to invariant-theoretic questions, proved to be useful in other realms of mathematics such as combinatorics.[344] The case of invariant theory thus underscores the general activity of nineteenth-century British mathematicians in supporting and contributing to a growing number of periodical publication venues for mathematics at home and abroad.

An Overview of Analytic Geometry in Nineteenth-Century Britain

Like those on algebra, articles on analytic geometry occupied a much larger portion of the mathematical literature in British scientific journals for 1837 to 1867 than they

[344]For the advances, especially by David Hilbert, that rivaled, and eventually supplanted, the British approach to invariant theory, see Karen Hunger Parshall, "The One-Hundredth Anniversary of the Death of Invariant Theory?" *The Mathematical Intelligencer* 12 (1990): 10-16.

had earlier in the nineteenth century. In fact, the percentage of articles devoted to analytic geometry more than doubled to 18.9% for the mid-nineteenth-century period.[345] It is not surprising that analytic geometry, so intimately connected to algebra, experienced a similar surge in popularity. The overview of analytic geometry that follows investigates the factors related to and distinct from algebra that influenced interest in analytic geometry among nineteenth-century British mathematicians.

Analytic geometry formed one plank in the platform for the introduction of analytical methods into the Cambridge curriculum during the early nineteenth century. The 1802 article, "On the Independence of Analytical and Geometrical Investigation and on the Advantages to be Derived from their Separation," in which Robert Woodhouse tackled the problem of negatives and imaginaries in algebra, also advocated the extension of algebra to geometry. While he argued for the excision of geometric methods from what he considered analytic considerations, Woodhouse encouraged injecting algebra into problems traditionally handled with synthetic geometry.[346]

At the time Woodhouse published this article, students at Cambridge had no textbook devoted exclusively to analytic geometry; a short appendix at the end of James Wood's *Algebra* furnished their only common reference to the subject.[347] The negative effect of this limited coverage of the study of analytic geometry at Cambridge

[345]The percentage of mathematical articles and pages devoted to analytic geometry for our three periods are: 7.9%, 8.0%, respectively for 1800-1836, 18.9%, 17.4% for 1837-1867, and 14.9% and 14.2% for 1868-1900.

[346]Koppelman, p. 178. Woodhouse's article is also discussed in the overview of algebra above.

[347]W.W. Rouse Ball, *A History of the Study of Mathematics at Cambridge* (Cambridge: University Press, 1889), p. 129. James Wood was Master of St. John's College, Cambridge, and wrote his *Algebra* as part of his four-volume *Principles of Mathematics and Natural Philosophy* of 1795-1799. *Ibid.*, p. 110.

was compounded by the fact that the subject matter of the Tripos was limited to topics covered in textbooks accessible to Cambridge students.[348] In fact, in the Tripos examinations for 1800 to 1820, the coverage of analytic geometry was in general limited "to areas and loci, in which little more than the mode of representation by means of abscissæ and ordinates are involved."[349]

Cambridge students finally received a textbook devoted to analytic geometry in 1826. In that year, Henry Parr Hamilton, Ninth Wrangler for 1816, published *The Principles of Analytic Geometry*, "a Cambridge equivalent of continental texts on analytic geometry."[350] Finding Cambridge students lacking in algebraic skill, Hamilton incorporated more diagrams and detail and surveyed fewer topics in his subsequent 1828 textbook, *An Analytical System of Conic Sections*, than in his 1826 work.[351] In addition to his algebraic reforms, in 1833 George Peacock tried to supplement the accounts of analytic geometry available to Cambridge students by publishing anonymously a *Syllabus of Trigonometry, and the Application of Algebra to Geometry*, which he republished in 1836. John Hymers, Second Wrangler for 1826, extended Hamilton's work with his own textbook, *A Treatise on Conic Sections and the Application of Algebra to Geometry*, of 1837. This text became the standard source for analytic geometry for Cambridge students for much of the nineteenth century[352] and

[348] *Ibid.*, p. 128.
[349] *Ibid.*, p. 129.
[350] Becher, "Whewell," p. 19.
[351] *Ibid.*, pp. 19-20.
[352] In 1889, Ball wrote that Hymers's book "remained the standard work until the publication of the text-books still in use." Ball, *History of Mathematics at Cambridge*, p. 130.

was "designed to wean the student from the synthetic to the analytic."[353]

The Tripos reflected the introduction of these textbooks on analytic geometry at Cambridge. As noted, by the 1840s, "analysis [had become] the primary road to success in the Tripos," and Cambridge students preparing for the examination "neglected synthetic geometry, ignored Newtonian mathematics, and devoted their time to the study of algebraic operations."[354] Analytic geometry, like algebra, suffered from Whewell's mid-century backlash against analysis;[355] however, like algebra, analytic geometry had already endeared itself to many at Cambridge; moreover, by the Tripos reforms of mid-century, Cambridge mathematicians and others around Britain had access to a resource that we will discuss below that encouraged the study of analytic geometry for research and not just for an examination.

In his 1876 address upon retiring as President of the London Mathematical Society, Henry Smith lamented the lack interest in subjects such as number theory by British mathematicians as compared with their great activity in analytic geometry. He told his audience that

---

353 Becher, "Whewell," p. 20.

354 *Ibid.*, pp. 22-23.

355 *Ibid.*, pp. 23,42. While only about one-seventh of the Tripos questions for 1844 asked for synthetic-geometric solutions, over 40% called for such approaches in the 1854 Tripos. *Ibid.* Rouse Ball commented that "[t]he use of analytical methods spread from Cambridge over the rest of the country, and by 1830 they had almost entirely superseded the fluxional and geometrical methods. It is possible that the complete success of the new school and the brilliant results that followed from their teaching led at first to a somewhat too exclusive employment of analysis; and there has of late been a tendency to revert to graphical and geometrical processes. That these are useful as auxiliaries to analysis, that they afford elegant demonstrations of results which are already known, and that they enable one to grasp the connection between different parts of the same subject is universally admitted, but it has yet to be proved that they are equally potent as instruments of research. To that I may add, that in my opinion the analytical methods are peculiarly suited to the national genius." Ball, *History of Mathematics at Cambridge* p. 123. Opinions similar to Ball's can be seen in the case study below.

> I am convinced that nothing so hinders the progress of mathematical science in England as the want of advanced treatises on mathematical subjects. We yield the palm to no European nation for the number and excellence of our text-books of the second grade — I mean, such text-books as are intended to guide the studies of the undergraduate within the courses prescribed by our University examinations in honours. But we want works adapted to the requirements of the student when his examinations are over— works which will carry him to the frontiers of knowledge in various directions, which will direct him to the problems which he ought to select as the objects of his own researches, and which will free his mind from the narrow views he is too apt to contract while 'getting up' subjects with a view to passing an examination, or a little later in his life, while preparing others for examination. Can we doubt that much of the preference for geometrical and algebraical speculation which we notice among our younger mathematicians is due to the admirable works of Dr. Salmon; and can we also doubt that, if other parts of mathematical science had been equally fortunate in finding an expositor, we should observe a wider interest in, and a juster appreciation of, the progress which has been achieved?[356]

The expositor referred to in Smith's remarks was George Salmon of Trinity College, Dublin. Unlike so many of his colleagues at TCD who researched synthetic geometry, Salmon was, like Cayley, mainly attracted to the analytic approach to geometry. The two mathematicians had first met in 1848 when Cayley was visiting Dublin in order to attend William Rowan Hamilton's lectures on quaternions; this meeting marked the beginning of a lifelong friendship between Cayley and Salmon.[357] The first research they conducted together was also probably the most surprising: through their correspondence, they found that 27 lines lie on a cubic surface. No lines lie entirely on a surface of degree n in three dimensional complex projective space if $n > 3$, and for $n < 3$ there are infinitely many lines.[358] Cayley found that for non-singular cubic

[356]H.J.S. Smith, "On the Present State," pp. 26-27.
[357]Crilly, *Mathematician Laureate*, chapter 6, p. 29.
[358]A surface of degree n is defined by a homogeneous polynomial of degree n.

surfaces, there are finitely many lines, and Salmon found the exact number.[359] Cayley published this result, giving credit to his collaborator, in 1849 in the *Cambridge and Dublin Mathematical Journal*.[360] This result, in the estimation of Rod Gow, "remains one of the deepest and most intriguing subjects in algebraic geometry."[361] Cayley continued to publish research on the cubic surface and its associated planes, lines, and points; in general, this topic "was a constant source of exploration in the nineteenth century and gave rise to a substantial literature."[362]

In the same year he began his research relationship with Cayley, Salmon also published *A Treatise on Conic Sections* for TCD students; however, the audience for this text soon expanded well outside the College's boundaries. Salmon's remarks at the beginning of the text indicate that TCD was as impoverished of texts on analytic geometry in 1849 as Cambridge had been in the early 1820s. In writing *Conic Sections*, he explained that "[i]t was not my original intention to publish an independent treatise on Analytical Geometry, but rather a supplement to the ordinary elementary works on that subject... [However,] I found some inconvenience from the fact, that there was no single work in general use among the students of this College [TCD], to which I could refer for elementary information... This deficiency I have attempted to supply in the following pages."[363]

---

[359] Gow, "Mathematical Work and Influence," pp. 36-37.
[360] Arthur Cayley, "On the Triple Tangent Planes of Surfaces of the Third Order," *Cambridge and Dublin Mathematical Journal* 4 (1849): 118-132.
[361] Rod Gow, "George Salmon 1819-1904," in *Creators of Mathematics: The Irish Connection*, ed. Ken Houston (Dublin: University College Dublin Press, 2000), pp. 37-45 on pp. 42-43.
[362] Crilly, *Mathematician Laureate*, chapter 6, p. 32.
[363] George Salmon, quoted in Gow, "Mathematical Work and Influence," pp. 42-43.

While most of Salmon's text is concerned with a treatment of analytic geometry for undergraduates (indeed, the first eight chapters roughly cover the same ground as Hymers's text), it also contains a final chapter on "Geometrical Methods" that caught the attention of research mathematicians. In this chapter, Salmon included some of the fundamental machinery of projective geometry, an area of mathematics that attracted many British mathematicians during the second half of the nineteenth century.[364] The work of the French projective geometer, Jean Victor Poncelet, particularly influenced Salmon's treatment of the area. After describing the method of projections, Salmon pointed his reader to Poncelet's 1822 *Traité des propriétés projectives des figures* and wrote that "I shall be glad if the slight sketch here given induces any reader to study a work, from which I have perhaps derived more information than from any other theory of curves."[365] The French geometer later admitted that Salmon's *Conic Sections* saved his *Traité* from being forgotten.[366] Projective geometry could be studied using both analytic and synthetic methods; in the *Conic Sections*, for example, Salmon applied coordinates to the subject.[367] (For the viewpoints of nineteenth-century British mathematicians on these geometric approaches, see the case study below.)

The topics included in the last chapter of Salmon's *Conic Sections* expanded to multiple chapters in the text's later editions. Besides this expansion, a new chapter

[364]Recall the discussion of projective geometry in the second section of this chapter.
[365]George Salmon, quoted in Gow, "Mathematical Work and Influence," p. 47.
[366]*Ibid.*, pp. 52-53.
[367]Crilly, *Mathematician Laureate*, chapter 6, p. 30.

applying invariant theory to systems of conics was added.[368] Salmon emphasized the relationship between invariant theory and geometry in his 1859 text devoted exclusively to the former theory, *Lessons Introductory to the Modern Higher Algebra*: "invariants, then, are functions of the coefficients expressing certain fixed properties of the curve or surface which are independent of our choice of axes; such as the condition that a curve or surface should have a double point, &C. Covariants represent certain other curves or surfaces having a fixed relation to the given one, independent of our choice of axes."[369]

Earlier in the 1850s, Sylvester had also seen much potential in the application of invariant theory to geometry. During this period, Sylvester was "hard at work to affect an algebrization of geometry."[370] In an 1851 article in the *Philosophical Magazine* on "An Enumeration of the Contacts of Lines and Surfaces of the Second Order," Sylvester wrote that "[g]eometry, to be properly understood, must be studied under a universal point of view... In this way only... we may hope to see accomplished an organic and vital development of the science."[371] Karen Parshall has explained that "the 'universal point of view' that developed was precisely the algebraic theory of invariants."[372]

Cayley further developed the connection between geometry and invariant theory in

[368] *Ibid.*, p. 47.
[369] George Salmon, *Lessons Introductory to the Modern Higher Algebra*, p. 52 quoted in Gow, "Mathematical Work and Influence," pp. 57-58.
[370] Parshall, "The Mathematical Legacy," p. 253.
[371] James Joseph Sylvester, "An Enumeration of the Contacts of Lines and Surfaces of the Second Order," *Philosophical Magazine*, 4th ser., 1 (1851): 119-140 or *The Collected Mathematical Papers* 1: 219.
[372] Parshall, "The Mathematical Legacy," p. 253.

his "Sixth Memoir on Quantics" of 1859. In particular, using the idea of the cross-ratio and conic he called the Absolute, Cayley formulated a definition of distance, which remained invariant under projection and section. With this innovation, Euclidean geometry could be considered as a special case of projective geometry.[373] In the hands of the German mathematician, Felix Klein, Cayley's idea of distance also provided a projective interpretation of non-Euclidean geometry that was subsequently embraced and pursued during the 1880s by a number of British mathematicians, including Clifford, Arthur Buchheim, Homersham Cox, and Robert Heath.[374]

Sylvester's and Cayley's work on invariant theory provided much of the theoretical material for Salmon's *Modern Higher Algebra*, and Cayley actually authored parts of the later editions of Salmon's other two texts, *A Treatise on the Higher Plane Curves* of 1852 and *A Treatise on the Analytic Geometry of Three Dimensions* of 1862, which concerned analytic geometry over two and three dimensions. Four years after the publication of the latter text, Salmon became Regius Professor of Divinity at TCD, a position, he said, that "left me no leisure to make acquaintance with recent mathematical discoveries, or even to keep up any memory of what I previously had known."[375] In his increasing isolation from current mathematical developments, Salmon greatly appreciated Cayley's help in editing and making additions to his 1852 and 1862 texts.[376]

While Salmon effectively exited the world of mathematical research after becoming

[373]Richards, *Mathematical Visions*, p. 130.
[374]*Ibid.*, p. 145.
[375]Salmon, quoted in Gow, "Mathematical Work and Influence," p. 56.
[376]Gow, "Mathematical Work and Influence," pp. 56, 64.

Professor of Divinity in 1866, his influence on that world continued to be felt for the rest of the nineteenth century. His textbooks, which ran into multiple editions, formed a reference for research mathematicians. In fact, about 87 articles published in the *Proceedings of the London Mathematical Society* between 1866 and 1900 cited Salmon's texts.[377] These works were also translated into French and German. The German translations, in one opinion, were to a great extent responsible for "a new spirit [that] came over geometrical teaching" in Germany.[378]

As Salmon's work was welcomed abroad, the geometrical work of foreign scholars was welcomed into Britain. For example, Ludwig Schläfli, Professor of Mathematics at the University of Bern, used the *Philosophical Transactions* to communicate his research in analytic geometry. His 1863 paper "On the Distribution of Surfaces of the Third Order into Species" extended Cayley and Salmon's work on cubic surfaces and was an extension of two articles Schläfli had published earlier in the *Quarterly Journal of Pure and Applied Mathematics.* Cayley, in fact, communicated the Swiss mathematician's work to the Royal Society and supplied parenthetical remarks to the article.[379] The German mathematician, Julius Plücker, who had made stunning contributions to analytic geometry during the 1820s and 1830s and had then turned his attention to physics, marked his reentry into geometrical research on the pages of the *Philosophical Transactions of the Royal Society of London.* There, in 1865,

[377] *Ibid.*, p. 41. Salmon's influence did not end in 1900; Gow found a 1996 citation of Salmon's texts in a mathematical paper. *Ibid.*, p. 67.

[378] J.T. Merz, quoted in *ibid.*, p. 39.

[379] Ludwig Schläfli, "On the Distribution of Surfaces of the Third Order into Species, in Reference to the Absence or Presence of Singular Points, and the Reality of their Lines," *Philosophical Transactions of the Royal Society of London* 153 (1863): 193-241 on p. 193.

he published a memoir "On a New Geometry of Space," in which he presented a three-dimensional interpretation of four dimensions by recognizing that "[t]he geometrical constitution of space, hitherto referred either to points or to planes, may as well be referred to right lines."[380] Of his return to geometry, he reported that, "[b]eing encouraged by the friendly interest expressed by English geometricians, I have resumed my former researches, which have been entirely abandoned by me since 1846."[381] In their research on analytic geometry, British mathematicians both found in and provided inspiration for geometers abroad.

The study of analytic geometry in nineteenth-century Britain thus drew its strength from a variety of sources. Textbooks devoted to analytic geometry encouraged the study of the area by undergraduates who were also drawn to study algebra. These texts further encouraged the extension of the analytic geometry by research mathematicians, who made internationally recognized contributions to the area.

Case Study: British Views on the Analytic Approach to Geometry, 1837-1867

In December, 1848, the editors of the *Philosophical Magazine* published a letter from an unusual correspondent. Writing that "I can no longer bear it should be thought that I have made a wrong balance, or consented to an unequal division of property," the author proceeded to clear his name. After proving that he had been unjustly accused of allowing one party to be robbed "of its birthright without any

[380] Julius Plücker, "On a New Geometry of Space," *Philosophical Transactions of the Royal Society of London* 155 (1865): 725-791 on p. 725. For more on the British reception of higher dimensions in geometry, see Richards, *Mathematical Visions*, pp. 57-59.

[381] Julius Plücker, "Fundamental Views regarding Mechanics," *Philosophical Transactions of the Royal Society of London* 156 (1866): 361-380 on p. 361.

compensation," the correspondent concluded that "I do not go for damages: but I think I have a right to such reparation as can be made by inserting demonstration of the following properties in future works on conic sections." The author then listed these properties that gave a more symmetric treatment of hyperbolas and ellipses and closed his letter with, "I am, Gentlemen, yours to command, The General Equation of the Second Degree."[382] Had analytic geometry taken such a firm hold on British mathematics that a quadratic equation felt bold enough to write to the *Philosophical Magazine*? In fact, British mathematicians during the middle third of the nineteenth century held a variety of opinions about the effectiveness and rigor of analytic versus synthetic methods in geometry.

The nineteenth-century debate about these methods centered mainly around their application to projective geometry. As soon as Poncelet introduced his principle of continuity in an article to Gergonne's *Annales de mathématiques pures et appliqueés*, his referee, Augustin-Louis Cauchy, criticized the principle as a "bold induction" and "capable of leading to manifest errors."[383] Camps defending the two methods emerged on the Continent, with the Swiss mathematician, Jakob Steiner, the German Karl Georg Christian von Staudt, Michel Chasles in France, and Luigi Cremona in Italy aligned with the "methodological purity" of synthesis, while the Germans August Ferdinand Möbius and Julius Plücker led the mathematicians attracted to analysis.[384]

[382]Anonymous, "On a Property of the Hyperbola," *Philosophical Magazine*, 3rd ser., 33 (1848): 546-548.

[383]Augustine-Louis Cauchy, quoted in *DSB*, s.v. "Poncelet, Jean Victor." For more on Poncelet's work and the criticism surrounding it, recall the introduction to this chapter.

[384]Gray, "Projective Geometry," p. 903.

As British mathematicians imported analytical tools from the Continent, they developed their own views on the virtues of the synthetic and analytic approaches to geometry. A decade before Poncelet first incited Cauchy to argue for the rigor of analysis, the Edinburgh mathematician, John Playfair, had challenged his colleagues to apply analysis to a famous piece of British geometry.[385] In 1746, Matthew Stewart, then a candidate for the mathematics chair at Edinburgh, had secured his position through the publication of his "General Theorems" on geometry. While he received acclaim for these theorems, which concern polygons circumscribed and inscribed about a circle, Stewart did not give demonstrations for them, and only in 1805 were they finally proven.[386] These proofs followed synthetically, and Playfair, in the *Edinburgh Review*, suggested that

> whoever would make a very extensive addition to the field in which... analysis may be exercised, and one in which much novelty may be expected, will do well to look into those properties of the circle which are given without the demonstrations, in the *General Theorems* of the late Dr. Matthew Stewart... [T]he difficulties they will present even to those who come armed with that powerful instrument [of analysis], will be felt as a high eulogium on a Genius, which, without such assistance, and employing only the antient [sic] geometry, was equal to such arduous investigations.[387]

Three decades after Playfair's comments, Robert Ellis, at the time a Cambridge undergraduate, rose to the challenge in an article published in the *Cambridge Mathematical Journal.* After presenting his proofs of the theorems, Ellis explained that

[385]For the opinions of other early nineteenth-century Edinburgh mathematicians about analysis versus synthesis in geometry, see Alex D.D. Craik, "Geometry versus Analysis in Early 19th-Century Scotland: John Leslie, William Wallace, and Thomas Carlyle," *Historia Mathematica* 27 (2000): 133-163.

[386]Robert Leslie Ellis, "Analytical Demonstrations of Dr. Matthew Stewart's Theorems," *Cambridge Mathematical Journal* 2 (1839-41): 271-276 on p. 271.

[387][John Playfair], "A Treatise on Plane and Spherical Trigonometry," *Edinburgh Review* 17 (1810): 122-135 on p. 129.

while "[t]he fundamental formula of our analysis is perhaps not new; the geometrical applications which we have made of it appear to be original."[388] By 1844, Thomas Stephen Davies, Mathematical Master at the Royal Military Academy at Woolwich, had provided further analytical demonstrations of the theorems in both the *Transactions of the Royal Society of Edinburgh* and the *Cambridge and Dublin Mathematical Journal.*[389]

Like the "General Theorems" of Stewart, the theorems of Pascal and Brianchon concerned in- and circumscribed polygons and formed a focus of activity for analytic geometers in Britain. In 1639, Blaise Pascal had discovered that the intersection points of the three pairs of opposite sides of a hexagon inscribed in a conic are collinear.[390] Over a century and a half later, Charles Julien Brianchon, a student under Gaspard Monge at the École polytechnique, proved in the *Journal de l'École polytechnique* the dual of Pascal's theorem: three diagonals of a hexagon circumscribed about a conic section have a common point of intersection.[391]

Brianchon proved his theorem using Pascal's, but the Cambridge MA John William Lubbock felt "it ... desirable to obtain a direct proof of this curious theorem."[392] In

[388]Ellis, "Analytical Demonstrations," p. 276.

[389]Thomas Stephen Davies, "An Analytical Discussion of Dr. Matthew Stewart's General Theorems," *Transactions of the Royal Society of Edinburgh* 15 (1844): 573-608; and "Analytical Investigations of Two of Dr. Stewart's General Theorems," *Cambridge and Dublin Mathematical Journal* 1 (1846): 229-238. A decade earlier, Davies had also developed a system of spherical coordinates that "preserves his name in the list of well-known mathematicians." *DNB*, s.v. "Davies, Thomas Stephens." Thomas Stephens Davies, "On the Equations of Loci Traced upon the Surface of the Sphere, as Expressed by Spherical Coordinates," *Transactions of the Royal Society of Edinburgh* 12 (1833-34): 259-362

[390]*DSB*, s.v. "Pascal, Blaise."

[391]John William Lubbock, "On a Property of the Conic Sections," *Philosophical Magazine*, 3rd ser., 13 (1838): 83-86 on p. 83. Charles Julien Brianchon, "Sur les surfaces courbes de deuxième degré," *Journal de l'École polytechnique* 6 (1806): 297-311.

[392]Lubbock, p. 83.

an 1838 article in the *Philosophical Magazine*, he used coordinates to prove the theorem analytically in the case of the parabola and maintained that his method "may be extended to all conic sections generally."[393]

Reviewing the existing proofs of Brianchon's theorem in 1839, Ellis noted that "the Geometrical method is more easily applied than the Analytical to these cases, and accordingly all the proofs given have depended on geometry, with the exception of the one published by Mr. Lubbock."[394] Regarding Lubbock's proof as "tedious, and not remarkable for symmetry and elegance," Ellis supplied in the *Cambridge Mathematical Journal* another analytical proof of the theorem for the case of the parabola.[395] William Walton, Eighth Wrangler for 1836, noted that "I am not aware that up to the present time any purely algebraical demonstrations have been given for the cases of the ellipse and the hyperbola" in the theorem, and he supplied "this deficiency" in the fourth volume of the *Journal*.[396] About 100 pages later in the *Journal*, Percival Frost, Second Wrangler and First Smith's Prizeman for 1839, gave yet another analytical proof of the theorem.[397]

For both Salmon and Cayley, the dual of Brianchon's Theorem became a particular "enduring interest."[398] Cayley, for example, gave in an 1843 issue of the *Cambridge Mathematical Journal* a new twist on a well-proven theorem by using determinants

[393] *Ibid.*, p. 86.
[394] Robert Leslie Ellis, "On Some Properties of the Parabola," *Cambridge Mathematical Journal* 1 (1837-1839): 204-207 on p. 204.
[395] *Ibid.*
[396] William Walton, "On Brianchon's Hexagon," *Cambridge Mathematical Journal* 4 (1843-1845): 163-167 on p. 164.
[397] Percival Frost, "On Brianchon's Hexagon," *Cambridge Mathematical Journal* 4 (1843-1845): 277-279.
[398] Crilly, *Mathematician Laureate*, chapter 6, p. 29.

to prove Pascal's theorem.[399] In the same year, after seeing still another analytic proof of Pascal's and Brianchon's theorems in the current volume of the *Philosophical Magazine*, Salmon directed his audience to the "best analytical demonstration of Pascal's" theorem found in Gergonne's *Annales.*[400] Despite the abundance of proofs, Salmon gave his own proof of Brianchon's theorem "because it leads at once to the corresponding property of surfaces of the second degree."[401] Taking the dual, Salmon obtained a surface analogue of Pascal's theorem: "Take any three plane sections of a surface of the second degree; through any two of them a pair of cones can be drawn. The six vertices of these cones are in the same plane, and each set of three on the same right line."[402] Salmon noted that this new property, while recognized by Poncelet, had never been connected to Pascal's theorem.[403]

Sylvester, who worked so closely with Cayley and Salmon on invariant theory, also had something to say about Pascal's and Brianchon's theorems. Referring to a demonstration of Pascal's theorem he had given in the September, 1850 issue of the

---

[399]Arthur Cayley, "Demonstration of Pascal's Theorem," *Cambridge Mathematical Journal* 3 (1843-1845): 18-20.

[400]George Salmon, "On the Properties of Surfaces of the Second Degree which Correspond to the Theorems of Pascal and Brianchon on Conic Sections," *Philosophical Magazine*, 3rd ser., 24 (1844): 49-51 on p. 50.

[401]*Ibid.*, p. 50

[402]*Ibid.*, p. 51.

[403]Thomas Weddle, at the time Mathematical Master at the National Society's Training College, Battersea, also considered analogues to Pascal's and Brianchon's theorems in space in a series of articles in the *Cambridge and Dublin Mathematical Journal.* Cayley informed him that some of his results had been anticipated by Otto Hesse at the University of Königsberg. Michel Chasles had also proven some of Weddle's result earlier, but sent an encouraging letter to the mathematician. Thomas Weddle, "On the Theorems of Space Analogous to Those of Pascal and Brianchon in a Plane," *Cambridge and Dublin Mathematical Journal* 4 (1849): 26-55; 5 (1850): 58-69; and 6 (1851): 114-135. Weddle's first contribution to the *Journal,* in fact, was a short note on Pascal's theorem. For a discussion of this series, recall chapter 4.

Philosophical Magazine,[404] Sylvester pointed out that

> ...the demonstration...applied equally to Brianchon's theorem. This remark is of the more importance, because the fault of the analytical demonstrations hitherto given of these theorems has been, that they make Brianchon's a consequence of Pascal's, instead of causing the two to flow simultaneously from the application of the same principles. No demonstration can be held valid in *method*, or as touching the essence of the subject-matter, in which the indifference of the duadic law [or method of duals] is departed from. Until these recent times, the analytic method of geometry, as given by Descartes, had been suffered to go on halting as it were on one foot. To Plücker was reserved the honour of setting it firmly on its two equal supports by supplying the complementary system of coordinates.[405]

In 1829, Plücker had introduced the concept of line coordinates, which supplied "an immediate analytic counterpart to the geometric principle of duality."[406] With this new tool, dual theorems could be demonstrated by means of separate analytic proofs that "flow simultaneously," instead of by means of one theorem depending on the analytic proof of the other along with the synthetic conception of the dual. Sylvester also made his preference for exclusively analytic methods clearly known in an 1866 article to the *Philosophical Magazine.* Referring to theorems that seem to be more easily arrived at by synthetic, rather than analytic means, Sylvester stated that "[i]n the nature of things such advantage can never be otherwise than temporary. Geometry may sometimes appear to take the lead of analysis, but in fact precedes it only as

[404]James Joseph Sylvester, "An Instantaneous Demonstration of Pascal's Theorem by the Method of Indeterminate Coordinates," *Philosophical Magazine* 37 (1850): 212, or *The Collected Mathematical Papers,* 1: 138.

[405]James Joseph Sylvester, "Additions to the Articles, 'On a New Class of Theorems,' and 'On Pascal's Theorem'," *Philosophical Magazine* 37 (1850): 363-370, or *The Collected Mathematical Papers,* 1: 151.

[406]Carl B. Boyer, *History of Analytic Geometry* (New York: Scripta Mathematica, 1956) p. 250; and Julian Lowell Coolidge, *A History of Geometrical Methods* (Oxford: University Press, 1940; reprint ed., New York: Dover Publications, Inc., 1963), pp. 145-146.

a servant goes before his master to clear the path and light him on his way. The interval between the two is as wide as between empiricism and science, as between the understanding and the reason, or as between the finite and the infinite."[407]

Despite the disposition for analytic methods shown by British mathematicians in the examples above, not everyone in Britain during the middle third of the nineteenth century belonged to the analytic camp. Recall that Salmon was an exception at Trinity College, Dublin with his analytic researches; although many geometric articles emerged from TCD, they were usually written from the synthetic point of view. When asked about the preponderance of such research in Dublin, William Rowan Hamilton remarked to Augustus De Morgan that "I think there *is* a greater, or at least a more general aptitude for pure geometry in Ireland than in England. The Fellows of T.C.D. are nearly all geometers, and some of them are extremely good ones."[408] One TCD Fellow, Richard Townsend, tried to present an entirely synthetic discussion in his paper to the *Cambridge and Dublin Mathematical Journal*, "On the Problem to Determine in Magnitude, Position, and Figure, the Surface of the Second Order which Passes through Nine Given Points." However, he was stopped by a lemma given by Otto Hesse that "[t]he polar planes of a fixed point with respect to a system of surfaces of the second order which pass through seven points will all

[407] James Joseph Sylvester, "Astronomical Proclusions: Commencing with an Instantaneous Proof of Lambert's and Euler's Theorems, and Modulating Through a Construction of the Orbit of a Heavenly Body from Two Heliocentric Distances, the Subtended Chord, and the Periodic Time, and the Focal Theory of Cartesion Ovals, into a Discussion of Motion in a Circle and its Relation to Planetary Motion," *Philosophical Magazine*, 4th ser., 31 (1866): 52-76, or *The Collected Mathematical Papers*, 1: 519-541 on p. 521.

[408] William Rowan Hamilton to Augustus De Morgan, 9 February, 1852, quoted in Gow, "Mathematical Work and Influence," p. 35.

turn round a fixed point."[409] Townsend lamented that "I have endeavoured without success to find a purely geometrical proof either of this Lemma or its reciprocal.... [W]ere such obtained, the whole investigation from the beginning would be entirely geometrical."[410] Townsend was more successful in the next volume of the *Cambridge and Dublin Mathematical Journal* when he proved synthetically a theorem on confocal surfaces given by his colleague Salmon "some years ago."[411]

Hirst also valued the synthetic approach to geometry. Recall from chapter 6 that he attended the lectures of the synthetic geometer, Jakob Steiner, after completing his doctoral thesis on analytic geometry at the University of Marburg. Hirst considered Steiner to have "a power of insight possessed by no other living geometer, perhaps,"[412] and in the opinion of one of Hirst's obituarists, "Steiner did much to determine the ultimate bent of [Hirst's] mathematical investigations."[413] In his journal, Hirst wrote of one "little interesting talk [Hirst and Steiner had had] on his system of Synthetical Geometry, and its relation to Analysis. The latter he would by no means annihilate, and pleads justly that heretofore it has but had too great pre-eminence to the detriment of Synthesis." Hirst's offer during that talk to produce an English

[409] Richard Townsend, "On the Problem to Determine in Magnitude, Position, and Figure, the Surface of the Second Order which Passes through Nine Given Points," *Cambridge and Dublin Mathematical Journal* 4 (1849): 241-252 on p. 251. Interestingly, Townsend states that this lemma was given by Salmon in an examination paper for 1843. Recall the overview on mathematical physics and mechanics above for a similar situation regarding Stokes's Theorem.

[410] *Ibid.*, p. 252.

[411] Richard Townsend, "On a Theorem in Confocal Surfaces of the Second Order," *Cambridge and Dublin Mathematical Journal* 5 (1850): 177-178 on p. 177.

[412] Thomas Archer Hirst quoted in J. Helen Gardner and Robin J. Wilson, "Thomas Archer Hirst – Mathematician Xtravagant. Part III," *American Mathematical Monthly* 100 (1993): 619-625 on p. 623.

[413] A[ndrew] R[ussell] F[orsyth], "Obituary of Fellows Deceased," *Proceedings of the Royal Society of London* 52 (1892): xii-xiv on p. xii.

translation of his work was the "finishing stroke" in "the old fellow's indifference towards me [that had]... been somewhat relaxing before."[414]

The next year in the *Cambridge and Dublin Mathematical Journal*, Hirst published his translation of Steiner's "Two New Methods of Defining Curves of the Second Order."[415] Some of Steiner's theorems had appeared there before, but they had been subjected to "simple algebraical demonstrations;"[416] with Hirst's translation, Steiner's synthetic methods, and not just the theorems he reached with them, received notice.[417]

As his translation of Steiner's work in Britain shows, Hirst was a clear supporter of synthetic geometry. His support also shines through in his review of Salmon's *Conic Sections* for the *Philosophical Magazine*: "[w]e do not wish here to revive the old and useless discussion on the comparative merits of the algebraic and geometric methods; both have undoubtedly their advantages, and both are indispensable... [however] the fact cannot be disputed, that the very facility with which results can be obtained algebraically, may indirectly prevent that intimate acquaintance with the properties of curves which a rigid geometrical investigation also secures."[418]

[414]Thomas Archer Hirst, 21 November, 1852, quoted in Gardner and Wilson, p. 624.

[415]Jakob Steiner, "On Two New Methods of Defining Curves of the Second Order, Together with New Properties of the Same Deducible Therefrom," *Cambridge and Dublin Mathematical Journal* 8 (1853): 227-249.

[416]Jakob Steiner, "On Certain Geometrical Theorems," *Cambridge and Dublin Mathematical Journal* 6 (1851): 160-167 on p. 160.

[417]Hirst also counted the Italian mathematician, Luigi Cremona, as a friend and communicated his synthetic work to the *Oxford, Cambridge, and Dublin Messenger of Mathematics.* Luigi Cremona, "The Fourteen-Points Conic," *Oxford, Cambridge, and Dublin Messenger of Mathematics* 3 (1866): 13-14; and "On Normals to Conics, a New Treatment of the Subject," *Oxford, Cambridge, and Dublin Messenger of Mathematics* 3 (1866): 88-93.

[418][Thomas Archer Hirst], "Review of *A Treatise on Conic Sections by G. Salmon*," *Philosophical Magazine*, 4th ser., 10 (1855): 441-442, quoted in Gow, "Mathematical Work and Influence," pp. 51-52.

A more fervent but related defense of synthetic methods appeared in the 1838 remarks of Sir William Hamilton, the Edinburgh logician (not to be confused with the Irish founder of quaternions). Analytic methods to Hamilton were like "running a railroad through a tunneled mountain... [bringing] us, by a short and easy transit, to our destined point, but in miasma, darkness, and torpidity." A synthetic point of view, on the other hand, was to Hamilton like "crossing the mountain on foot" and "allows us to reach it only after time and trouble, but feasting us at each turn with glances of the earth and of the heavens, while we inhale the pleasant breeze, and gather new strength at every effort we put forth."[419]

As the analogies of slaves, masters, tunnels and footpaths show, attitudes in Britain during the middle third of the century about the relative merits of synthetic and analytic geometry differed greatly. One result of these differences was the publication of geometrical results constantly proved and reproved by the rival methods. In Salmon's opinion, this outcome was not altogether negative because "[i]t is sometimes useful to apply both geometrical and analytical methods to the same problem, each throwing light on the results of the other."[420] With this perspective, these articles enriched rather than duplicated the mathematics published in British scientific journals.

Conclusion

Nineteenth-century British scientific journals contained an impressive array of mathematics; as tables 7B and 7C show, the interests of these authors spread into

[419]William Hamilton, quoted in Craik, "Geometry versus Analysis," p. 143.

[420]George Salmon, "On the Number of Normals which Can Be Drawn From a Given Point to a Given Surface," *Cambridge and Dublin Mathematical Journal* 3 (1848): 46-47 on p. 46.

all 12 of the *Jahrbuch* areas. Even more numerous than the mathematical topics that formed the subjects of articles in these journals are the factors that encouraged their investigation. The education of the authors, the preferences of the editors, the "hot" problems of the day, the controversies of the moment, the encouragement of collaborators, the new book or journal that had just arrived in the mail, and the chance at national (or at least mathematical) glory all motivated the members of the publication community to write and submit articles on particular areas.

While it indicates that the mathematics in nineteenth-century British scientific journals covered a wide spectrum, our classification of the mathematical articles in these journals also points to five areas that occupied, on average, almost 70% of the mathematical pages and articles. Three of these areas, organized under the *Jahrbuch* headings of "Mathematical Physics," "Mechanics," and "Geodesy and Astronomy," clearly owed much of their prominence to the Cambridge "mixed" mathematical education of many members of the publication community. However, the other two predominant areas, "Algebra" and "Analytic Geometry," could also thank Cambridge, and especially its reforms spawned by the *mania analytica*, for giving its students a taste for these fields of pure mathematics.

Besides institutional curricula, individual British mathematicians promoted activity in certain areas of mathematics. Thomson and Stokes, for example, contributed articles to the *Cambridge Mathematical Journal* in order to expose the *Journal*'s readers to what they saw as neglected areas of applied mathematics, such as hydrodynamics. Salmon wrote his textbooks in order to give organized presentations of algebra and analytic geometry that were lacking in English, and he thereby encouraged British mathematicians to conduct research in these areas. Sylvester and Cayley "beat the bushes" of British science in order to obtain funds for their invariant theory campaign, an initiative that Sylvester especially saw as one of national pride. These examples suggest that nineteenth-century British mathematics was not left to develop aimlessly; instead, the promotion of certain mathematical areas among British mathematicians formed a clear agenda among some in the higher echelons.

Given the existence of personal agendas that shaped the contours of British mathematics, do the articles themselves suggest a domain of mathematics unique to Britain? Certainly, the authors of these articles neglected some areas (such as number theory and the Cauchian — and later Weierstrassian — approach to analysis) that were actively pursued elsewhere; however, they adopted other mathematical areas (such as projective geometry and the Lagrangian approach to calculus) that had begun on the Continent. Moreover, they established the foundations of still other areas of mathematics (such as invariant theory and many approaches to applied mathematics) that were emulated abroad. Recall from chapter 6 that foreign mathematicians provided, especially later in the nineteenth century, a considerable proportion of the articles classified in tables 7B and 7C. Thus, and to address our question, while the mathematics covered in British scientific journals was not identical to what was being pursued in other national mathematical contexts, it was increasingly the result of the intertwining interests of British and foreign mathematicians engaged in international communication.

Besides the topics of the articles considered in tables 7B and 7C, the raw number of articles also illuminates an important point about British research in mathematics. Namely, the rate at which this research was being published was dramatically increasing. As more lines for communication among the nineteenth-century British mathematical publication community were established, a growing (as we saw in chapter 5) group of mathematicians had much more to say to each other. As tools for communication, public records for establishing priority, vehicles for extending or disagreeing with results, and catalysts for new research, mathematical articles begat mathematical articles, and the publication community became ever more connected.

These articles thus provide a clear window into a engaging, dynamic century of mathematics. As we have shown here, they give a sense of the ebb and flow of mathematical interests in Britain during the nineteenth century, and they indicate the rising tide of British mathematical activity and communication over this century.

Chapter 8: Contours of the Nineteenth-Century British Mathematical Publication Community

While the preceding chapters have considered nineteenth-century British mathematics from the three perspectives of journals, mathematicians, and mathematics, they have not incorporated these three perspectives into a comprehensive survey from 1800 to 1900. It is to this task that we now turn. We first reorganize our findings chronologically in an effort to illuminate the ways in which technical and social factors interwove to form the fabric of nineteenth-century British mathematics.

In this chronological survey, we will use a three-part division of the nineteenth century that has appeared throughout the quantitative findings of this dissertation. These three divisions, 1800 to 1836, 1837 to 1867, and 1868 to 1900, mark not so much distinct periods as evolutionary stages in the development of the nineteenth-century British mathematical publication community. The following overview of nineteenth-century British mathematics suggests characterizations of these three stages and thus provides insights into the evolution of the publication community. Further distilling the findings of this overview and the dissertation in general, we then consider what the mathematical publication community reveals about the broader issues of professionalization, stratification, and internationalization over the course of the century.

A Chronological Summary of the British Mathematical Publication Community, 1800-1900

At the beginning of our first stage, a mathematician who wanted to publish in a British journal had basically three choices: the *Transactions* of a general scientific society; one of a few commercial, general scientific journals; or a minor mathematical serial. Each option offered opportunities for communication; however, each also involved considerable drawbacks. To submit a mathematical article to a society's *Transactions*, a mathematician had either to be a member of the society or to have the paper communicated by a society member. After submission to, for example, the Royal Society of London, the article might be rejected and never returned, a serious consequence at a time when copying manuscripts was a time-consuming and costly enterprise. If, in fact, the article was selected for publication, the author still had to be prepared to wait possibly for years to see it in print, and then more often than not sandwiched between two completely unrelated articles.[1] Commercial, general scientific journals, as we saw in chapter 3, had a much faster publication rate and none of the exclusive requirements of society membership; still, an author wanting to publish a mathematical article in one of these journals was limited in page length and had to vie for space with articles from a variety of other scientific fields. No such competition arose in minor mathematical serials devoted entirely to mathematics, but they lacked the prestige and continuity of both the scientific society journals and to a lesser extent the commercial journals. Compared with the *Philosophical Transactions of the Royal Society of London*, which was at this time nearing its sesquicentennial, these minor mathematical serials could be very transient affairs indeed, sometimes lasting only a few numbers or volumes. Moreover, they were a product of a problem-solving tradition and, as such, imposed limits — literal or perceived — on the depth of the

[1]For more on the long time lag in scientific society journals early in the nineteenth century, recall chapter 2.

articles published.

By the 1820s, publication options for mathematics in Britain, which had remained relatively static for two decades, began to increase. In 1822, the Cambridge Philosophical Society began publishing its *Transactions*, a general science journal soon dominated by Cambridge mathematicians. The same year saw the publication of the first volume of the *Memoirs of the Royal Astronomical Society.* Although this journal was, by the nature of its society, primarily concerned with astronomy, research in mathematics, recognized as the bedrock on which the foundation of astronomy stood, was welcomed into its pages. With the *Memoirs*, mathematicians could enjoy the stability, prestige, and ample pages of a national scientific society journal without having to compete with a myriad of other disciplines for room and attention. By 1831, the British Association for the Advancement of Science (BAAS) and its *Report* also helped British mathematicians communicate with each other somewhat separate from the din of general science. The BAAS Section A brought these mathematicians together within a more specialized context of mathematics and physical science, while the *Report* published the pronouncements of mathematicians elected as Section A presidents and provided room for extensive and influential surveys on the progress of mathematical science.[2] Besides gaining more specialized forums in which to communicate, British mathematicians were also able to communicate more quickly with the establishment of society *Proceedings* beginning in the late 1820s. As more timely and succinct publication organs, these *Proceedings* shortened the

[2]For more on these reports and presidential addresses, recall chapter 7.

long lag time that had traditionally existed between the volumes of society journals. New societies, publications, and publication formats thus resulted in new journals for Britain's mathematical practitioners during the first stage in the evolution of the nineteenth-century British mathematical publication community.

Who exercised these new publication options in this first stage? Of the mathematicians publishing via the scientific societies, most were affiliated with a British university, either as a student, Professor, or Fellow. While this fact considered at face value seems to suggest the existence of a university network of mathematicians similar to what exists today, if we take into account the duties and motives defining the context of these university positions, we come away with a very different conclusion.

While many students were encouraged to study mathematics, especially at Cambridge and Dublin, this study was for many a means to an end. A mastery of a prescribed set of mathematical topics was necessary for a high Tripos finish at Cambridge or for a high Fellowship examination finish at Dublin; a high finish helped open the doors to fellowships, which then led to promising positions in the universities, the Church, and the government.[3] In this way, the study of mathematics played an integral role in securing livelihoods for Cambridge and Dublin students; however, these jobs did not encourage or compensate the pursuit of mathematics.

Even the professorship of mathematics, a prime position for a young mathematically inclined Fellow, did not include mathematical research in its job description.

[3]Jeremy Gray, "Mathematics in Cambridge and Beyond," in *Cambridge Minds*, ed. Richard Mason (Cambridge: University Press, 1994), pp. 86-99 on p. 87; and John Gascoigne, "Mathematics and Meritocracy: The Emergence of the Cambridge Mathematical Tripos," *Social Studies of Science* 14 (1984): 547-584 on p. 561.

While a professorship is considered today the archetypical position for a professional mathematician, it was, during the years of 1800 to 1836, available only in extremely limited numbers. Moreover, recall from chapter 5 that while professors, especially at Cambridge and Oxford, did enjoy enough leisure for private research, they were not encouraged to do so and were usually isolated from the students and fellows of their universities.

Given that their workplaces did not foster a cohesive network of communication for mathematics, British mathematicians embraced the scientific societies. They actively participated as society officers, and their mathematical contributions from 1800 to 1836 occupied from 13% to over 36% of the pages of these general societies' *Transactions*, a quarter of the pages of the reports of the BAAS,[4] and almost 8% of the pages in the Royal Astronomical Society's *Memoirs*.

Unlike that of the society journals, the contributorship of minor mathematical serials, especially for our first stage of 1800 to 1836, drew heavily from a recreational, problem-solving tradition outside the university. However, the university and recreational mathematical spheres were hardly disjoint; in particular, several university-trained mathematicians developed their tastes for mathematics as young problem-solvers. The university and recreational spheres also met in several instances when these serials were produced by professors at England's military colleges. These military-college-centered serials contained original research and mathematical inno-

[4]This figure includes only the "Reports" section of the *BAAS Report*. It does not include the "Transactions" section, which often provided abstracts of papers presented at the BAAS meetings and then published elsewhere. For a complete table of these percentages, recall chapter 3.

vations alongside questions and answers.

Some of these innovations involved the introduction of continental methods into the British approach to the calculus. Wallace and Ivory, on the pages of the Leybourn's *Repository*, and the members of the Analytical Society in their short-lived *Memoirs*, advocated a Lagrangian, algebraic approach to the calculus. As this approach took root among British mathematicians and in the Cambridge Tripos, it fostered a distinctly British emphasis on operational methods applied to differential and integral calculus and geometry as well as an increasingly abstract approach to algebra. Besides its connection to the analytical reforms, algebra benefited from the attention of British mathematicians dissatisfied with the unjustified, eighteenth-century use of negative and complex numbers. Differential and integral calculus, analytic geometry, and algebra reflected this new attention through their portion of mathematical articles and pages in British scientific journals during our first stage of nineteenth-century British mathematics. In the sample of journals considered in chapter 7, these areas each claimed around 7% of the mathematical pages and articles from 1800 to 1836.

If these pure mathematical subjects were substantially represented in British scientific journals, the "mixed" mathematical topics central to the Cambridge curriculum reigned supreme. Geodesy, astronomy and mathematical physics alone accounted for over one half of the articles and mathematical pages in the journals from 1800 to 1836. While applied mathematics drew from an illustrious British tradition dating back to Isaac Newton, the application of continental notation and techniques, particularly to geodesy and astronomy, piqued British interest, indicating an awareness of international innovations and a desire to keep up with them.

This glimpse of the mathematics published, the jobs and society affiliations of those publishing, and the journals to which they contributed, suggests that the years from 1800 to 1836 characterize what may be called a stage of gestation of the nineteenth-century British mathematical publication community. Mathematical researchers, isolated or overworked in academic posts, church parishes, and elsewhere, used scientific societies to connect with each other and to communicate their research. Along with their support of these societies, these mathematicians enthusiastically embraced any publication venue conducive to mathematical communication, whether a society journal or one lone mathematician's commercial venture. They were not, however, ready to organize *as a group* to launch any such venues of their own. *This* would distinguish the first from the second stages.

The second stage in the evolution of the nineteenth-century British mathematical publication community, 1837 to 1867, began with the foundation of the *Cambridge Mathematical Journal*. As we described in chapter 4, Duncan Gregory and his Cambridge colleagues established an organ that explicitly encouraged the publication of original mathematical research. The time was right for such a venture; whereas the *Memoirs of the Analytical Society* a quarter of a century earlier had encountered mainly indifference, the *Mathematical Journal*, animated to a large degree by the reforms of the former members of the Analytical Society, enjoyed success. To be sure, the *Journal* was not a national publication organ for research mathematicians;

its contributorship, in fact, was composed mainly of Cambridge students and young fellows. However, it provided a place where students cut their mathematical teeth, and it was from this group that the impetus for high-level mathematical journals in Britain later derived.

In 1846, the *Cambridge and Dublin Mathematical Journal* not only continued its predecessor's call for original research but also extended that call to a wider group of British and foreign contributors. The excellent manuscript archive of the *Journal*'s editor, William Thomson, provides an intimate and detailed view of his editorial decisions. It is in these letters that we see Thomson, along with his loyal group of volunteer referees, trying to set publication standards that promoted quality mathematical research without alienating the economic base, that is, the readers of and contributors to the *Journal*. The *Cambridge and Dublin Mathematical Journal* thus set itself apart from the minor mathematical serials; in a telling instance, Steven Fenwick, co-editor of the *Mathematician*, had his contribution to the *Journal* rejected. However, the *Journal* was not immune to the economic troubles that plagued the serials, and the fortunes of the *Journal* further declined with Thomson's disengagement from the enterprise.

Out of the failure of the *Cambridge and Dublin Mathematical Journal* in 1854 came the *Quarterly Journal of Pure and Applied Mathematics*. This third incarnation of the *Cambridge Mathematical Journal* began with an impressive first volume that contained contributions from a variety of international contributors. This latter feature was indicative of the international reputations of the *Quarterly Journal*'s editorial team, including Sylvester, Cayley, Stokes, and Hermite. While it did not maintain this high degree of international participation, the *Quarterly Journal* clearly aimed to present the contributions of a national collection of mathematicians on an international mathematical stage.

In the *Quarterly Journal*, British mathematicians had not only a new publication venue exclusively devoted to mathematics through which they could communicate but also the first such British journal in which they could also regularly communicate with mathematicians from abroad. In embracing this journal, however, they did not reject the ones on which they had relied earlier. While survival of the fittest certainly occurred at the level of individual journals, the development of British journals for mathematics during the nineteenth century was, at the genre level, a cumulative process, rather than one of natural selection. The *Quarterly Journal* provides an instructive example of this point. As a national mathematical journal evolved from a student journal, the *Quarterly Journal* represented a new genre for mathematical articles but left a vacuum in its earlier genre of the university-centered student mathematical journal. Instead of signaling the death of the student genre, however, this evolution encouraged the foundation in 1862 of the *Oxford, Cambridge, and Dublin Messenger of Mathematics*, a journal that subsequently enlarged its audience but continued to cater to young researchers throughout the nineteenth century. The genre of minor mathematical serials was also reinvigorated by the establishment in 1864 of the *Mathematical Questions with Their Solutions Taken from the Educational Times.*

As new journals for mathematics emerged, British mathematicians actually simultaneously became more active in general scientific journals. They also increasingly occupied positions of influence in these societies. As presidents, they could promote mathematics from their high visibility positions. As secretaries, they often acted as the principal editors of the society journals, and as such, they promoted mathematics at a more internal, pervasive level. The mathematical members of these societies also volunteered to help with refereeing, a process that underwent profound development and wide adoption among these societies during the middle third of the nineteenth century.[5] The referee reports of the Royal Society of London, in particular, indicate the standards mathematicians were developing to evaluate the work of their colleagues and the seriousness with which these mathematicians regarded that evaluation task.

Like those during our first stage, the mathematicians who contributed articles from 1837 to 1867 to the growing publication venue for mathematics usually had university affiliations. The foundation of University College, London in 1826 (at that time known as London University) marked the beginning of an era in the establishment of new universities throughout Britain and the concomitant establishment of new professorships of mathematics. Moreover, at Cambridge, Oxford, and, to a lesser extent, Dublin, the growing importance of examinations spawned a cottage industry of private mathematical coaches. Mathematicians thus had more job opportunities; however, these new jobs exclusively compensated their teaching responsibilities and provided them with little leisure time for research. Without an academic infrastructure supporting mathematical research, mathematicians could, and did, find more

[5]For more on the evolving refereeing process, recall chapter 2.

time for research in other occupations such as country parson, lawyer, or businessman.[6]

Like their occupations, the mathematical areas in which these mathematicians conducted their research was diverse. Analytic ideas that had been gestating during the first third of the nineteenth century blossomed during the middle third into active lines of research on the calculus of operations, invariant theory, and the analytic approach to projective geometry. In embracing the "continental," algebraic approach to the calculus, however, the British isolated themselves from other "continental" approaches, such as the Cauchian-style analysis being developed by European mathematicians during these years and work in analysis of Karl Weierstrass. Some idea can be gained of the extent of this isolation through the low percentage of research on series in the mathematical articles and pages of British scientific journals; in fact, series was one of the few areas of research activity on Cauchian-style analysis being pursued at all by British mathematicians. Differential and integral calculus, algebra, and analytic geometry, on the other hand, experienced their highest percentages of the nineteenth century during this middle stage; from 1837 to 1867, the latter two fields, in fact, accounted for over one-third of the overall mathematical production measured in chapter 7.[7]

Despite and, to some extent, because of these analytic gains, applied mathematics still dominated the mathematical pages of British scientific journals. An anti-analytic

[6]Recall chapter 5 for examples of mathematicians in these occupations.

[7]Differential and integral calculus actually slightly increased its share of articles after 1868 but decreased its share of pages. Recall tables 7B and 7C.

backlash, led by William Whewell, ensured that traditional Cambridge "mixed" mathematics prevailed in the Tripos, and the indefatigable George Airy worked to keep this emphasis in the Smith's Prize examination. While the Cambridge strength in traditional "mixed" mathematics centered around the mathematically established areas of mechanics and optics, Irish mathematicians supplemented their ability in optics, and Scottish mathematicians added their expertise and interest in the more experimentally based realms of heat, magnetism, and electricity.[8] Although, on the whole, the applied mathematical areas maintained their strong positions in British scientific journals, geodesy and astronomy occupied a much smaller share of the mathematical production than they had during our first stage. John Couch Adams's astronomical work enjoyed spectacular success, but the number of articles published in the area stayed roughly the same and was increasingly outnumbered by other mathematical works published in the growing publication landscape.

The years from 1837 to 1867 can thus be characterized as a stage of construction of a complex infrastructure of mathematical journals that encouraged and aided the development of mathematical researchers. Minor mathematical serials could pique the imagination of a young student; with the mathematical tools honed at a British university, usually Cambridge or Dublin, the recent graduate could begin publishing original mathematical articles and receive the constructive criticism of peers through a student journal; by submitting later mathematical articles to a scientific society journal, the *Cambridge and Dublin Mathematical Journal*, or the *Quarterly Journal*,

[8] Recall the overview on mathematical physics and mechanics in chapter 7.

the developing researcher could be imbued with the mathematical standards being developed by an ambitious, internationally aware group of mathematicians. With this publication infrastructure, built upon the bedrock of scientific societies and major mathematical educational centers, it is no surprise that in 1865, there was sufficient support for the foundation of the London Mathematical Society (LMS) and its *Proceedings*, a society and a journal practically born as full-grown enterprises.[9]

While the years from 1837 to 1867 represent for British mathematics a stage of infrastructure building, the remainder of the nineteenth century represents a stage of definition and consolidation. Through strict refereeing policies, the LMS further defined the standards for measuring the quality of research-level mathematics in Britain. At the same time, the society also made it clear that its concerns lay firmly within the province of research-level mathematics. Mathematicians interested in pedagogical issues, therefore, formed their own societies, the Association for the Improvement of Geometrical Teaching (AIGT), and to some extent, the Edinburgh Mathematical Society (EMS), to meet their emerging needs.[10] Recall from chapter 3 that mathematicians with both pedagogical and research interests joined together on the pages of *Nature* to communicate mathematical news and opinions and to engage in controversies. The fact that mathematicians embraced the communication possibilities of a non-technical, general science weekly suggests that they increasingly had more to

[9]Adrian C. Rice, Robin Wilson, and Helen Gardner cite November 1866 as a date by which the LMS had reached national proportions. Adrian C. Rice, Robin J. Wilson, and J. Helen Gardner, "From Student Club to National Society: The Founding of the London Mathematical Society in 1865," *Historia Mathematica* 22 (1995): 402-421 on p. 415.

[10]For a discussion of the AIGT and the EMS, recall chapter 2.

say to British science and each other, not just about mathematics itself, but about the community infrastructure solidifying around them.

During this third definitional stage, changes in the publication venues for British mathematics continued to be, at the genre level, cumulative rather than selective. Minor mathematical serials, as well as general science journals supported by scientific societies and operated as commercial ventures, remained a part of the mathematical publication landscape. Moreover, research mathematicians continued to publish in each genre. However, because of the refereeing standards established by researchers in the premier scientific society and mathematical journals, the publication boundaries became for potential contributors, in effect, a system of concentric circles of tightening exclusivity.

As members of the publication community, students continued to be strong contributors during the last third of the nineteenth century. Another large contingency of publishing mathematicians worked, as they had during the earlier decades of the nineteenth century, as professors, fellows, or in other university-related positions. While these job titles stayed the same, their job descriptions and responsibilities were slowly changing into what we would today identify with a career in mathematics. The revocation of celibacy requirements at Cambridge and Oxford during the 1880s and at Dublin forty years earlier encouraged fellows to view their positions as lifelong careers rather than as stepping stones to other types of employment.[11] University reforms distributed the job of teaching mathematics more evenly between professors,

[11]For more on these fellowship requirements, recall chapter 5.

fellows, and private coaches. Cambridge professors, who had played an active role in the 1883 reform of the Smith's Prizes, took advantage of its new dissertation format to develop mathematical research relationships with students.

Outside the universities, school teachers extended their publication of mathematical articles beyond the genre of the minor mathematical journal, a development owing, in large measure, to the foundation of pedagogically focused societies and their periodicals. Although private individuals, businessmen, clergymen, and lawyers still belonged to the mathematical publication community, they increasingly became the exception rather than the rule.

While the job opportunities and descriptions, the societies, and the journals for mathematics had changed over the nineteenth century in Britain, one thing remained the same — the dominance of applied topics in the mathematics published in British scientific journals. Although the foothold of geodesy and astronomy in these journals slipped further during the last third of the nineteenth century, mathematical physics and mechanics remained strong. Moreover, several applied mathematicians during this stage were recognized as lions of British science and were rewarded with medals, presidencies of scientific societies, and international acclaim.

Pure mathematics, however, had some lions of its own. Pure mathematicians made up much of the small but powerful group that established international ties, published their work abroad, and encouraged foreigners to publish their work in British journals. This higher echelon of the publication community exhibited an increased international awareness, which was also reflected through a higher proportion of articles devoted to subjects previously neglected in Britain, such as number theory and function theory. Publication activity in pure, synthetic, and elementary geometry, areas with traditional roots in both Britain and the Continent, also increased during this stage, bolstered in part by new, pedagogically oriented journals such as the *Mathematical Gazette.* Activity in algebra, analytic geometry, and differential and integral calculus dropped off from from its mid-century high but still accounted for about one-third of the mathematical production during this third stage.

As this chronological summary shows, the British mathematician of 1800 was in some ways very different from and, in other ways, similar to the British mathematician of 1900. As the century progressed, mathematicians in Britain communicated their work in an increasingly varied publication landscape with separate but interconnected genres of journals. They also had more job options and more opportunities to interact as researchers, teachers, or recreational mathematicians. As the infrastructure of British mathematics improved, however, the publication venues and societies characteristic of 1800 were not neglected. Also not neglected by the members of the publication community was applied mathematics, which, despite the ebbing and flowing of mathematical interests among these members, remained a constant throughout the nineteenth century.

This chronological overview of the nineteenth-century British mathematical publication community suggests several general conclusions about the evolution of mathematics and mathematicians in nineteenth-century Britain. In particular, it highlights in various ways the processes of professionalization, stratification, and internationalization, to which we now turn.

Vocation or Avocation? The Development of Professionalization in the Nineteenth-Century British Mathematical Community

In his article on the professionalization of nineteenth-century American science, Nathan Reingold pointed out that the diverse connotations and contexts surrounding professionalization makes the attempt to define this concept "a thankless task."[12] Indeed, the task of evaluating the extent of professionalization in nineteenth-century British mathematics can be both thankless and confusing, especially if we rely on modern-day definitions of the concept. With these cautions in mind, we use here a definition of professionalization entailing the emergence of organizations, publications, and occupations that encouraged and/or compensated mathematical research.

During the gestational stage from 1800 to 1836, while many of the British mathematicians publishing research held positions in academic institutions, they were not encouraged or specifically compensated to conduct research. Moreover, while British organizations and publications existed that encouraged mathematicians to conduct research, this encouragement occurred within the context of *general* science. Although they actively contributed to *general scientific* publications and organizations, British mathematicians *as a group* were not prepared to establish these structures for themselves. Thus, for this stage, "gestational" aptly describes the degree of professionalization in British mathematics.

[12]Nathan Reingold, "Definitions and Speculations: The Professionalization of Science in America in the Nineteenth Century," in *The Pursuit of Knowledge in the Early American Republic*, ed. Alexandra Oleson and Sanborn C. Brown (Baltimore and London: The Johns Hopkins University Press, 1976), pp. 33-69 on p. 34.

After a gestational stage within the structure of British general science, British mathematicians began constructing their own structures of professionalization. Two phenomena of our second stage of evolution, the foundation of British research-level mathematical journals and the enhancement of society journals with strict refereeing standards for mathematics, established publications that encouraged mathematical research. Another second-stage phenomenon, the foundation of the LMS, marked the establishment of a *specialized* organization that encouraged mathematical research. Therefore, by the end of the second evolutionary stage, British mathematical researchers were supported by several sturdy pillars of professionalization. Moreover, and exemplifying their credibility and influence, these journals and this society were emulated by American mathematicians establishing their own structures of professionalization after a similar stage of gestation from 1776 to 1876.[13]

The *American Journal of Mathematics* established at the Johns Hopkins University in 1878 was the first American mathematical journal to encourage original research since 1842; however, before its foundation, Hopkins president, Daniel Coit

[13]In their study of the emergence of a mathematical research community in America, Karen Parshall and David Rowe have characterized the years of 1776 to 1876 as the "first" period in the emergence of an American mathematical community. Of this period, they write that "the field [of mathematics] evolved not as a separate discipline but rather within the context of the general structure-building of American... science. The colleges formed a primary locus of scientific activity, but, by and large, they did little to encourage the pursuit of research for the advancement of science. At the same time, the concept of research in American science... emerged as scientists looked toward Europe as their model and measured themselves against the yardstick of European scientific achievement." Karen Hunger Parshall and David E. Rowe, *The Emergence of the American Mathematical Research Community, 1876-1900: J.J. Sylvester, Felix Klein, and E.H. Moore*, HMATH, vol. 8 (Providence: American Mathematical Society and London: London Mathematical Society, 1994), p. xiii. Moreover, their first period witnessed "the formation of an American *scientific* community which, loosely characterized, earned its living primarily through undergraduate teaching but which defined itself by the extracurricular research it presented before general scientific societies and published in books or general scientific journals." *Ibid.*, p. xiv.

Gilman, unsuccessfully tried to move the *Quarterly Journal of Pure and Applied Mathematics* to Baltimore.[14] Thomas Fiske first proposed the establishment of the New York Mathematical Society to his fellow graduate students at Columbia College after a six-month sojourn to England in 1887 where, after attending meetings of the LMS, he had "come away with lasting impressions of the importance of the shared mathematical experience."[15] When this new American society began publishing its *Bulletin* in 1891, it modeled it on the *Messenger of Mathematics*.[16]

While American research mathematicians emulated the LMS and British mathematical journals, they looked to Germany as a model for what Parshall and Rowe have identified as a crucial component in the emergence of a mathematical research community in America. As a means of occupational and organizational encouragement and compensation for mathematical research, this component forms under our definition an important factor in professionalization: the development of researchers "not merely interested in mathematics but who possessed the requisite knowledge *and* institutional support to educate the next generation of researchers."[17] Informed by the German research ethic, institutional mandates for research, and principles of *Lehr- und Lernfreiheit*, American research-oriented universities founded after the Civil War established graduate research schools in a variety of disciplines, including mathematics. British mathematicians at this time had no such graduate research

[14] *Ibid.*, p. 88. Benjamin Peirce's *The Cambridge Miscellany of Mathematics, Physics, and Astronomy* published mathematical research but lasted less than a year after its establishment in 1842.
[15] *Ibid.*, p. 267.
[16] *Ibid.*, p. 268.
[17] *Ibid.*, pp. 429-430.

schools. However, the first American research school of mathematics, established at Johns Hopkins University in 1876, was led by the British mathematician, Sylvester.[18] It is more than a little ironic that Sylvester, a British mathematician, began a research school for mathematics within a university setting in America before any such school existed in Britain. Moreover, he established this school over a decade *after* the foundation of the LMS and over a decade *before* the foundation of the New York (later American) Mathematical Society. What accounts for such disparity between the timelines in these factors of professionalization? In a word, tradition.

British mathematicians, working within a centuries-old institutional framework of which mathematics formed a central component could only *very slowly* make changes to its structure. The new American research-oriented universities, on the other hand, provided more conducive environments in which a driven group of mathematicians introduced new approaches to mathematical training. A case in point of this difference is the introduction of the PhD While the PhD did not reach Britain until 1917,[19] six such degrees had been awarded in mathematics in America by 1875, 21 by 1890, and over 100 by the turn of the century.[20] In the absence of this credential, British universities implemented their own advanced degree, the DSc, an innovation that not surprisingly was adopted at the 22-year-old University of London a quarter of a century before its 1883 introduction at Cambridge and 42 years before its introduction

[18] *Ibid.*, p. 53.

[19] Renate Simpson, *How the PhD Came to Britain: A Century of Struggle for Postgraduate Education* (Surrey, UK: The Society for Research into Higher Education, 1983), p. 135.

[20] Parshall and Rowe, p. 429.

at Oxford.[21] As the adoption of advanced degrees for science and mathematics shows, British universities, laboring under the heavy weight of tradition, could only gradually and on their own terms make changes to their institutional fabric.

British universities, hampered by tradition, were not ready or willing to offer graduate research programs in mathematics during the nineteenth century. However, British mathematics had produced the man chosen to lead the first school of mathematical research in America. These seemingly contradictory statements indicate that research-level mathematicians were being trained in nineteenth-century Britain, although not in universities with the training of future researchers as part of their institutional missions. Where, then, did this training occur?

In the absence of graduate research programs at British universities, the LMS and the genre of research-level mathematical journals in Britain provided much of the interaction and peer criticism critical to the training of research mathematicians. However, this does not imply that these mathematicians received their research training exclusively outside of the university setting. As the example of the *Cambridge Mathematical Journal* shows, a significant number of high wranglers and Prizemen graduated from Cambridge with the desire and the ability to conduct original research. Tripos preparation provided students with a sturdy mathematical foundation, especially in applied mathematics. The Smith's Prize examination allowed them to apply this training to mathematical investigations, that, while pre-set, required creativity and innovation. The role of the Smith's Prize in fostering mathematical research

[21]For a discussion of this degree, recall chapter 5.

only grew when the basis for the Prize switched to written dissertations in 1883. British universities, and especially Cambridge, adapted their own vehicles to provide training for research mathematicians. While certainly not within the context of a graduate research school, these vehicles nonetheless helped prepare students to publish original research, and so, represented key components of the professionalization of nineteenth-century British mathematics.

By 1900, the professionalization of mathematics in Britain had evolved to the point that the production of mathematical research was effectively *encouraged*; however, Britain still largely lacked occupations which *compensated* such endeavors. As noted throughout the chronological survey above, only during the third, definitional stage of evolution did the job expectations of university positions for mathematicians begin to approach their modern connotations. Even with the evolution of these job descriptions, British university mathematicians, in many cases, produced their mathematical research outside the domain of their institutional obligations. Without specific institutional directives to pursue mathematical research in these posts, many of these mathematicians created these expectations for themselves. Professionalization in the nineteenth-century British publication community, then, can be characterized by 1900 as a process in its early stages at the occupational level but to a large degree realized at the level of organizations and publications.

Concentric Circles: The Development of Stratification in the Nineteenth-Century British Mathematical Publication Community

As the forums and organizations for research mathematics became more professionalized in nineteenth-century Britain, they increasingly excluded the products and issues of pedagogical and recreational mathematics. Since these domains of mathematics certainly did not disappear, the need for other forums and organizations arose. Thus, the process of professionalization is intertwined with the concept of stratification, namely the process by which groups, made distinct through particular relationships to mathematics, communicate mathematical ideas through separate organizations and publications.[22]

Separate genres of publications existed for British mathematics throughout the nineteenth century. During our first evolutionary stage, minor mathematical serials existed alongside the journals of scientific societies and commercial, general science journals. By the second stage, separate mathematical journals aimed at students, teachers, and researchers emerged. At the organizational level, the LMS definitively oriented itself towards research-level mathematics, and, during the third definitional stage, the AIGT explicitly and the EMS to some extent were founded to address the needs of mathematical pedagogy.

By the end of the nineteenth century, the vehicles of stratification for British mathematics were fully in place; however, these vehicles were not used by fully *separate* groups of mathematicians. Research-level mathematicians such as Sylvester, Cayley, and Clifford contributed to the *Mathematical Problems...from the Educational Times* throughout the nineteenth century, and Hirst, one of the first British mathematicians to earn a German PhD, served as the first President of the AIGT.

[22]For more on stratification, see, for example, Jonathan R. Cole and Stephen Cole, *Social Stratification in Science* (Chicago: The University of Chicago Press, 1973); and David L. Roberts, "Albert Harry Wheeler (1873-1950): A Case Study in the Stratification of American Mathematical Activity," *Historia Mathematica* 23 (1996): 269-287.

The developing mathematical standards exercised through the refereeing and editing of articles in British research-level mathematical journals, however, meant that while mathematical researchers could publish in any mathematical journal genre they wished, recreational mathematicians and teachers were increasingly limited to their own journal genres.

As the stratum of nineteenth-century British mathematics with the clearest standards and boundaries, research-level mathematics can be examined for substratification. For this examination, we need to use a different definition of stratification from that above, because we are looking for separation *within* an already stratified set of organizations and publications. The definition used by Della Fenster and Karen Parshall in their "Profile of the American Mathematical Research Community: 1891-1906" nicely fits these needs.[23] Fenster and Parshall first considered the "most active" participants in their community, those who "faithfully published journal articles, gave talks at meetings of the [American Mathematical] Society or elsewhere, and/or served to promote the cause of mathematics through their involvement in such activities as elected office and committee or editorial work."[24] As the recurrent appearance of the names Cayley, Sylvester, Thomson, and Stokes in the case studies of chapter 7 and the society and journal investigations of chapter 2 and 4 reveals, research-level

[23]Della Dumbaugh Fenster and Karen Parshall, "A Profile of the American Research Community: 1891-1906," in *The History of Modern Mathematics*, vol. 3, ed. Eberhard Knobloch and David E. Rowe (Boston: Academic Press, 1994), pp. 179-227.

[24]*Ibid.*, p. 184. Fenster and Parshall also provided a numerical interpretation of their notion of "most active" within the context of their quantitative study of the first 15 years of publication of the *Bulletin of the New York* (later American) *Mathematical Society.* There, they defined a "most active" participant as one who published, talked, or served at least once per year, on average, from 1891 to 1906.

mathematics in Britain had its own "most active" champions who tirelessly worked to advance the agendas of research-level mathematics. Recall from chapter 5 that 92 domestic contributors published 20 or more articles in the journals of that chapter's prosopography. For the British case, we could perhaps also augment the definition of "most active" participant to include the 56 British mathematicians found in chapter 6 who contributed to international journals. At their second level, Fenster and Parshall defined "active" participants as completing an activity (giving a talk, publication, or service to the mathematical research community) at least once every five years.[25] While we have not measured the extent of all of these activities, the fact that well over half of the subjects in the prosopography of chapter 5 made less than three contributions to the study's journals suggests the existence of a large group of mathematicians engaged in, but not overly occupied with, research-level mathematics in Britain. Finally, Fenster and Parshall defined the "rank and file" as those who completed only one or two activities from 1891 to 1906 or on whom biographical information was unavailable.[26] Such a "rank and file" clearly existed in the British mathematical research community. Recall again from the prosopography of chapter 5 that almost 40% of the subjects made only one contribution to the sample of journals and that a substantial number of "unknowns" defied an extensive biographical search. Many of these contributors made only fleeting appearances on the pages of

[25] *Ibid.*, p. 188. "Service" for Fenster and Parshall includes membership in the American Mathematical Society, attendance at scientific society meetings or congresses, and the more intensive society service described in the definition of "most active" participants above.

[26] *Ibid.*, p. 192. Specifically, mathematicians not found in their biographical source of the *American Men of Science* are defined as "rank and file."

mathematical journals, only to recede into the background of the silent readers of mathematics in British scientific journals.

Stratification in nineteenth-century British mathematics, like professionalization, was complete in some respects and developing in others. The mathematical researchers had created solid boundaries around their enterprise, which was further subdivided into distinct levels of participation. The mathematical domains of recreation and pedagogy, however, formed increasingly exclusive concentric circles around the research core.

Entering the International Mathematical Arena: The Development of Internationalization in the Nineteenth-Century Publication Community

Along with stratification, internationalization was a process intertwined with the professionalization of the nineteenth-century British mathematical publication community. Here, we take internationalization to mean reciprocal relationships between mathematicians of different nations that resulted in shared language, methods, and research agendas for mathematics.[27]

Key insights into the development of internationalization in nineteenth-century mathematics can be found in the perceptions of British mathematics provided by Babbage and John Herschel quoted in chapter 1. The complaints of Herschel and Babbage in 1830 about the sorry state of British mathematics do not mark the low point of the field in Britain. In fact, as this dissertation has shown, British math-

[27]This definition borrows heavily from Karen Hunger Parshall and Adrian C. Rice, "The Evolution of an International Mathematical Research Community, 1800-1945: An Overview and an Agenda," in *Mathematics Unbound: The Evolution of an International Mathematical Community, 1800-1945*, ed. Karen Hunger Parshall and Adrian C. Rice (Providence: American Mathematical Society and London: London Mathematical Society, 2002), pp. 1-15, especially p. 11.

ematicians at this time were actively adopting new innovations from the Continent and pursuing new lines of research inspired by this work. What these complaints do mark is the emergence as early as the 1830s of an awareness and concern by British mathematicians for the recognition, reputation, and competitiveness of their work internationally. Irrespective of the state of mathematics in Britain in 1830, the outcries of Babbage and Herschel would have fallen on deaf ears had British mathematicians not recognized — or cared — about their reputation relative to those on the Continent.

As chapter 6 has shown, concrete manifestations of this international concern and national pride included the publication of British mathematical work in foreign journals as a means of building reputations at home and the simultaneous encouragement of foreign mathematicians to contribute their work to British journals in order to gain international validation. British mathematicians also proudly received foreign medals and memberships for their work, while they lobbied, at the same time, to give foreign mathematicians medals of and memberships to British scientific societies. It is important to note here that these international efforts sought both to bring Britain into the international community and the international community to Britain. Without the strong catalyst of national pride, the internationalizing efforts of British mathematicians could have been a situation of "every man for himself," abandoning British journals and societies for those of the Continent. Instead, members of the top echelon of British research mathematics actively promoted their home journals and societies and encouraged their approbation by foreign mathematicians.

Forty years after the comments of Babbage and Herschel, Michel Chasles's warning to French mathematicians, also quoted in chapter 1, of the ominous advance of British mathematics indicates the extent of internationalization among British mathematicians, but not when it is taken at face value. Germany, after all, was a much more immediate mathematical rival to France than Britain. Perhaps Chasles hoped to capitalize on old enmity between the British and the French in order to motivate his mathematical countrymen. However, if British mathematics had not been improving in the eyes of mathematicians internationally, Chasles's comments would have been dismissed by his colleagues. Instead, British mathematics represented a serious example in the first public expression "of the need for a learned society exclusively devoted to the mathematical sciences" in France.[28]

The remarks of Babbage, Herschel, and Chasles show that British mathematicians cared about their national reputation by 1830 and that they were beginning to be perceived as an emerging force in mathematics by foreign mathematicians as early as 1870. The manifestations of these remarks described above also indicate reciprocal relationships between British mathematicians and those of other nations. To what extent, however, did these relationships result in language, methods, and research agendas for mathematics shared between British mathematicians and the mathematicians of other nations? As the example of the early nineteenth-century adoption of the Lagrangian approach to calculus shows, initiatives that initially indicated the

[28]Hélène Gispert, "The Effects of War on France's International Role in Mathematics, 1870-1914," in *Mathematics Unbound: The Evolution of an International Mathematical Community, 1800-1945*, ed. Karen Hunger Parshall and Adrian C. Rice (Providence: American Mathematical Society and London: London Mathematical Society, 2002), pp. 105-121 on p. 106.

sharing of language and methods between British and foreign mathematicians could soon take on a particularly British flavor that seemed *passé* or uninteresting to mathematicians abroad. As the example of invariant theory shows, British and foreign (in this case, German) mathematicians also developed methods to the same research agendas that were mutually unintelligible. However, the example of invariant theory also demonstrates that British and foreign (in this case, American, Italian, and French) mathematicians could cooperate to develop an approach to a research agenda.

Finally, through the lens of journal publication, we can see from chapter 6 that although foreign participation in British journals was unsteady at times, it came from a geographically diverse collection of developed and emerging national mathematical communities. On the other hand, while the group of British mathematicians publishing abroad was small, at its core was a powerful group of (to use the previously quoted descriptor) "most active" participants who wanted to bring British mathematics to the international publication arena. Internationalization, like the related issues of stratification and professionalization, was thus a process incomplete but well underway in nineteenth-century British mathematical publication community.

Conclusion

British mathematics and mathematicians *circa* 1900 — not quite professionalized, not quite internationalized, and not quite stratified — were on the brink of incredible changes. What brought them to this point? Both encouraged yet hampered by a centuries-long tradition of mathematics in British universities, motivated yet alarmed by the advances of mathematics on the Continent, British mathematicians used and slowly adapted their country's scientific structures in the service of diverse agendas concerning the advancement of mathematical knowledge and the development of mathematical infrastructure. Scientific journals provided British mathematicians with a structure through which they could communicate, specialize, mobilize, and transmit the standards of their field.

In the chapters above, we have interwoven and supplemented the existing snapshots of nineteenth-century British mathematics, creating a broad but detailed landscape portrait. By using the length of the entire nineteenth century, we have presented an evolution of British mathematicians from working within the context of general science to building and defining their own structures for the promotion, advancement, and diffusion of mathematics. The breadth of the publication community has given us a sense of the mathematical interaction between a diverse group of mathematicians holding a variety of jobs, having a spectrum of educational backgrounds, and communicating through a variety of venues. Finally, the depth of the three perspectives of this dissertation has given us a development that is neither exclusively internal nor external and that highlights the interconnectedness of the technical and social factors behind nineteenth-century British mathematics. This dissertation has thus presented a three-dimensional picture of the development of the nineteenth-century British mathematical publication community.

REFERENCES

Manuscript Sources

Adams Papers, St. John's College, Cambridge.

Betti Archive, Scuola Normale Superiore di Pisa.

Kelvin Papers, University Library, Cambridge.

London Mathematical Society Papers, University College London.

Referees Reports, Royal Society of London.

Royal Astronomical Society Papers, London.

Stokes Papers, University Library, Cambridge.

Taylor & Francis Papers, St. Brides Library, London.

Taylor Papers, St. John's College, Cambridge.

Printed Sources

Abbott, Edward Abbott. *Flatland: A Romance of Many Dimentions.* 1884. Reprint, Princeton: Princeton University Press, 1991.

Adams, John Couch. "Reply to Various Objections Which Have Been Brought against his Theory of the Secular Acceleration of the Moon's Mean Motion." *Monthly Notices of the Royal Astronomical Society* 20 (1860): 225-240.

Addison, William Innes. *A Roll of the Graduates of the University of Glasgow, from 31st December, 1727 to 31st December, 1897, with Short Biographical Notes.* Glasgow: MacLehose, 1898.

Adrain, Robert. "A View of the Diophantine Analysis." *Liverpool Apollonius* no. 2 (1824): 86-91.

[Advertisement]. *Leeds Correspondent* 3 (1819-1821): 180.

"Advertisement." *Messenger of Mathematics* 1 (1871): iii-iv.

"Advertisement." *Philosophical Magazine* 42 (1813).

"Advertisement: Scientific Worthies." *Nature* 33 (1886): xxxiv.

Airy, George Biddell. "Cambridge Problems 1830, 1831." *Mathematical Repository* 6 (1835): 1-48.

_________. "On the Figure of the Earth." *Philosophical Transactions of the Royal Society* 116 (1826): 548-578.

_________. "Report on the Progress of Astronomy During the Present Century." *BAAS Report* (1832): 125-189.

Allman, George Johnston. "Greek Geometry from Thales to Euclid." *Hermathena* 3 (1879): 160-207; 4 (1883): 180-228; 5 (1885): 186-236, 403-432; and 6 (1888): 105-130, 269-278.

_________. *Greek Geometry from Thales to Euclid.* Dublin: Hodges, Figgis, 1889.

Alphabetical List of Graduates of the University of Edinburgh from 1859 to 1888. Edinburgh: J. Thin, 1889.

"The 'American Journal of Mathematics'." *Nature* 31 (1885): 189-190.

Amicus. *Leeds Correspondent* 4 (1822): 4.

Andrews, George E. "Preface." In *Percy Alexander MacMahon Collected Papers.* Vol. 1. Ed., George E. Andrews, pp. xv-xvii. Cambridge, MA and London: The MIT Press, 1978.

Anonymous. "On a Property of the Hyperbola." *Philosophical Magazine.* 3rd Ser. 33 (1848): 546-548.

Anonymous. "The Rev. G. Salmon's *Lessons Introductory to the Modern Higher Algebra.*" *Philosophical Magazine*, 4th Ser. 18 (1859): 67-68.

Archibald, Raymond Clare. "Notes on Some Minor English Mathematical Serials." *Mathematical Gazette* 14 (1929): 379-400.

Archibald, Thomas. "Mathematical Theories of Electricity and Magnetism to 1900." In *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences*, Ed. Ivor Grattan-Guinness. 2 Vol, 2: 1208-1219. London and New York: Routledge, 1994.

"Association for the Reform of Geometrical Teaching." *Nature* 3 (1870): 169.

Atkinson, Dwight. *Scientific Discourse in Sociohistorical Context: The Philosophical Transactions of the Royal Society of London, 1675-1975.* Mahway, NJ: Lawrence Erlbaum Associates, 1999.

Ausejo, Elena and Mariano Hormigón, Ed., *Messengers of Mathematics: European Journals (1800-1946)*. Madrid: Siglo XXI de España Editores, S.A., 1993.

"Avviso dei compilatori." *Annali di matematica pura ed applicata* 1 (1858): 5.

Babbage, Charles. *Passages from the Life of a Philosopher.* Ed. Martin Campbell-Kelley. New Brunswick, NJ: Rutgers University Press, 1994.

_________. *Reflections of the Decline of Science in England, and on Some of Its Causes.* London: B. Fellowes, 1830. Reprint, New York: New York University Press, 1989.

Ball, Robert. "Elliptic Space." *Nature* 33 (1885): 86-87.

_________. "The Non-Euclidean Geometry." *Hermathena* 3 (1877-1879): 500-541.

Ball, W.W. Rouse. *A History of the Study of Mathematics at Cambridge.* Cambridge: University Press, 1889.

_________. *A Short Account of the History of Mathematics.* 3rd ed., London: Macmillan and Co., 1901.

Barrow-Green, June. BRITMATH [database].

_________. "'A Corrective to the Spirit of Too Exclusively Pure Mathematics': Robert Smith (1689-1768) and his Prizes at Cambridge University." *Annals of Science* 56 (1999): 271-316.

_________. "William Burnside's Applied Mathematics." In *The Collected Papers of William Burnside*, Ed. Peter M. Neumann, A.J.S. Mann, and J.C. Thompson. Oxford: University Press, to appear.

Becher, Harvey W. "William Whewell and Cambridge Mathematics." *Historical Studies in the Physical Sciences* 11 (1980): 1-48.

_________. "Woodhouse, Babbage, Peacock, and Modern Algebra." *Historia Mathematica* 7 (1980): 389-400.

Beckers, Danny J. " 'Untiring Labour Overcomes All!' The Dutch Mathematical Society in European Perspective." *Historia Mathematica* 28 (2001): 31-47.

Bell, Andrew. "On the Determination of the Modulus of Elasticity of a Rod of any Material, By Means of its Musical Note." *Cambridge and Dublin Mathematical Journal* 3 (1848): 63-67.

"Benjamin Wilkinson, 1827-1916." *Proceedings of the Royal Society of London.* Ser. A 93 (1916-1917): xxxviii-xli.

Benson, Charles. "Trinity College: a Bibliographical Essay." In *Trinity College Dublin and the Idea of a University,* Ed. Charles Hepworth Holland, pp. 357-372. Dublin: Trinity College Dublin Press, 1991.

Berman, Morris. *Social Change and Scientific Organization: The Royal Institution, 1799-1844.* Ithaca: Cornell University Press, 1978.

Betti, Enrico. "Extract from a Letter of Signor Enrico Betti to Mr. Sylvester." *Quarterly Journal of Pure and Applied Mathematics* 1 (1855): 91-92.

________. "Sopra l'equazioni algebriche con più incognite." *Annali di matematica pura ed applicata* 1 (1858): 1-8.

Biermann, Kurt-R. *Die Mathematik und ihre Dozenten an der Berliner Universität, 1810-1933.* Berlin: Akademie-Verlag, 1988.

Biggs, N.L. "T.P. Kirkman, Mathematician." *Bulletin of the London Mathematical Society* 13 (1981): 97-120.

Biographie universelle, ancienne et moderne. Paris: A. T. Desplaces, 1843-1865.

Bipliopola. "Female Mathematicians." *Leeds Correspondent* 4 (1822): 116-120.

Boase, Frederic, Ed. *Modern English Biography.* London: Frank Cass & Co. Ltd, 1965.

Boole, George. "On the Application of the Theory of Probabilities to the Question of the Combination of Testamonies or Judgments." *Transactions of the Royal Society of Edinburgh* 21 (1857): 597-652.

________. "On the Calculus of Logic." *Cambridge and Dublin Mathematical Journal* 3 (1848): 183-198.

________. "On the Conditions by Which the Solutions of Questions in the Theory of Probabilities are Limited.," *Philosophical Magazine* 8 (1854): 91-98.

________. "Exposition of a General Theory of Linear Transformations" *Cambridge Mathematical Journal* 3 (1841-1843): 1-20.

________. "On a General Method in Analysis." *Philosophical Transactions of the Royal Society of London* 134 (1844): 225-82.

________. "Proposed Question on the Theory of Probabilities." *Cambridge and Dublin Mathematical Journal* 6 (1851): 286.

________. "On the Theory of Probabilities." *Proceedings of the Royal Society of London* 12 (1862-1863): 420-424.

________. "On the Theory of Probabilities and in Particular on Mitchell's Problem of the Distribution of the Fixed Stars." *Philosophical Magazine* 1 (1851): 521-530.

Boyer, Carl B. *History of Analytic Geometry.* New York: Scripta Mathematica, 1956.

Brianchon, Charles Julien. "Sur les surfaces courbes de deuxième degré." *Journal de l'École polytechnique* 6 (1806): 297-311.

Brioschi, Francesco. "Note sure deux théorèmes de géométrie." *Quarterly Journal of Pure and Applied Mathematics* 1 (1855): 368-370.

________. "Sur une propriété d'un déterminant fonctionnel." *Quarterly Journal of Pure and Applied Mathematics* 1 (1855): 365-367.

Broadbent, T.A.A. "The *Mathematical Gazette*: Our History and Aims." *Mathematical Gazette*, 186-194.

Brock, M.G. "The Oxford of Peel and Gladstone." In *The History of the University of Oxford: Nineteenth-Century Oxford, Part I*, Ed. M.G. Brock and M.C. Curthoys, pp. 7-71. Oxford: Clarendon Press, 1997.

Brock, William H. "The Development of Commercial Science Journals in Victorian Britain." In *Development of Science Publishing in Europe*, Ed. Arthur Jack Meadows, 95-102. Amsterdam: Elsevier Science Publishers, 1980.

________. "Foreword." In *Science in the Making: Scientific Development as Chronicled by the Historic Papers in the Philosophical Magazine* Vol. 2, Ed. E.A. Davis, pp. vii-xiii. London: Taylor & Francis, 1995.

Brock, William H. and Arthur Jack Meadows. *The Lamp of Learning: Taylor & Francis and the Development of Science Publishing.* London: Taylor & Francis, 1984.

Brooke, Christopher N.L., Ed. *A History of the University of Cambridge.* Vol. IV, *1870-1990*, by Christopher N.L. Brooke. Cambridge: University Press, 1993.

Buchwald, Jed Z. *The Rise of the Wave Theory of Light: Optical Theory and Experiment in the Early Nineteenth Century.* Chicago: University of Chicago Press, 1989.

Burnside, William. "The Theory of Functions." *Nature* 48 (1893): 169-170.

Burt, Janet. "The Development of the Mathematical Department of the Educational Times from 1847 to 1862." Unpublished Ph.D. diss., Middlesex University, 1998.

Burtchaeli, George Dames and Thomas Ulick Sadleir, Ed. *Alumni Dublinenses.* Dublin: Alex. Thom & Co., Ltd., 1935.

Buttmann, Günther. *The Shadow of the Telescope: A Biography of John Herschel.* New York: Charles Scribner's Sons, 1970.

Campbell, Neil and R. Martin S. Smellie. *The Royal Society of Edinburgh (1783-1983): The First Two Hundred Years.* Edinburgh: The Royal Society of Edinburgh, 1983.

Cannell, Doris Mary. *George Green: Mathematician and Physicist 1793-1841.* London: Athlone Press, 1993.

Carlson, C. Lennart. *The First Magazine: A History of the Gentleman's Magazine.* Menasha, WI: The George Banta Publishing Co., 1938.

Cassels, John William Scott. "The Spitalfields Mathematical Society." *Bulletin of the London Mathematical Society* 11 (1979): 241-258.

A Catalogue of the Graduates in the Faculties of Arts, Divinity, and Law of the University of Edinburgh since its Foundation. Edinburgh: Neill and Co., 1858.

Cayley, Arthur. "Addition to the Foregoing Paper." *Proceedings of the London Mathematical Society* 14 (1882): 88-91.

_________. "Demonstration of Pascal's Theorem." *Cambridge Mathematical Journal* 3 (1843-1845): 18-20.

_________. "Desiderata and Suggestions: No. 1 The Theory of Groups." *American Journal of Mathematics* 1 (1878): 50-52.

_________. "Desiderata and Suggestions: No. 2 The Theory of Groups." *American Journal of Mathematics* 1 (1878): 174-176.

_________. "Desiderata and Suggestions: No. 3 The Newton-Fourier Imaginary Problem." *American Journal of Mathematics* 2 (1879): 97.

_________. "Desiderata and Suggestions: No. 4 Mechanical Construction of Conformable Figures." *American Journal of Mathematics* 2 (1879): 186.

_________. "On the Finite Number of the Covariants of a Binary Quantic." *Mathematische Annalen* 34 (1889): 319-320

_________. "On Linear Transformations." *Cambridge and Dublin Mathematical Journal* 1 (1846): 104-122.

_________. "Mémoire sur les courbes du troisième ordre." *Journal de mathématiques pures et appliquées* 9 (1844): 285-293.

_________. "Mémoire sur les hyperdéterminants." *Journal für die reine und angewandte Mathematik* 30 (1846): 1-37.

_________. "A Memoir on the Theory of Matrices," *Philosophical Transactions of the Royal Society of London* 148 (1858): 17-37

_________."Note on the Composition of Infinitesimal Rotations." *Quarterly Journal of Pure and Applied Mathematics* 8 (1867): 7-10.

_________. "Note sur deux formules données par M.M. Eisenstein et Hesse." *Journal für die reine und angewandte Mathematik*, 29 (1845): 54-57.

_________. "Note sur la théorie des hyperdéterminants." *Journal für die reine und angewandte Mathematik* 42 (1851): 368-371.

_________. "Nouvelles recherches sur les covariants." *Journal für die reine und angewandte Mathematik* 47 (1854): 109-124.

_________. "On the Porism of the In-And-Circumscribed Polygon." *Philosophical Transactions of the Royal Society of London* 151 (1861): 225-239.

_________. "On the Progress of Theoretical Dynamics." *BAAS Report* (1857): 1-42.

_________."On the Representation of a Spherical or Other Surface on a Plane: A Smith's Prize Dissertation." *Messenger of Mathematics* 2 (1872): 36-37.

_________. "Second Memoir upon Quantics." *Philosophical Transactions of the Royal Society of London* 146 (1856): 101-126.

_________. "A Smith's Prize Dissertation." *Messenger of Mathematics* 4 (1874): 157-160.

_________. "A Smith's Prize Paper." *Oxford, Cambridge, and Dublin Messenger of Mathematics* 4 (1868): 201-26; 5 (1869-1870): 40-64, 182-203.

_________. "A Smith's Prize Paper and Dissertation." *Messenger of Mathematics* 3 (1873): 1-4; 165-183, 4 (1874): 6-8.

_________. "A Smith's Prize Paper 1877." *Messenger of Mathematics* 6 (1876): 173-182.

_________. "On a Smith's Prize Question, Relating to Potentials." *Messenger of Mathematics* 11 (1881): 15-18.

_________. "Solution of a Senate-House Problem." *Oxford, Cambridge and Dublin Messenger of Mathematics* 5 (1871): 24-26.

_________. "Solutions of a Smith's Prize Paper for 1871." *Messenger of Mathematics* 1 (1871): 37-47, 71-77, 89-95.

_________. "On the Theory of Groups as Depending on the Symbolical Equation $\theta^n = 1$." *Philosophical Magazine* 4th Ser. 7 (1854): 40-47; 7 (1854): 408-409; and 18 (1859): 34-37.

_________. "On the Theory of Linear Transformation." *Cambridge Mathematical Journal* 4 (1845): 193-209.

_________. "On the Triple Tangent Planes of Surfaces of the Third Order." *Cambridge and Dublin Mathematical Journal* 4 (1849): 118-132.

_________. "Two Smith's Prize Dissertations." *Messenger of Mathematics* 2 (1872): 145-149, 161-166.

Challis, James. "Report on the Present State of the Analytical Theory of Hydrostatics and Hydrodynamics." *BAAS Report* (1833): 131-152.

Chapman, Allan. "Private Research and Public Duty: George Biddell Airy and the Search for Neptune." *Journal for the History of Astronomy* 19 (1988): 121-139.

Chasles, Michel. "Considérations sur la méthode générale exposée dans la séance du 15 février - Différence entre cette méthode et la méthode analytique - Procédés générale de démonstration." *Comptes rendus* 58 (1864): 1167-1175.

Chubin, Daryl E. and Soumyo D. Moitra. "Content Analysis of References: Adjunct or Alternative to Citation Counting?" *Social Studies of Science* 5 (1975): 423-441.

Clarke, Edward Daniel. "Address Read at the First Meeting of the Cambridge Philosophical Society." *Transactions of the Cambridge Philosophical Society* 1 (1821): 1-7.

Clausius, Rudolf. "Ueber die bewegende Kraft der Wärme." Poggendorff's *Annalen* 79 (1850): 368-394, 500-524.

Clerke, Agnes M. *The Herschels and Modern Astronomy.* London: Cassell and Co., 1895.

Cole, Jonathan R. and Stephen Cole. *Social Stratification in Science.* Chicago: The University of Chicago Press, 1973.

Coolidge, Julian Lowell. *A History of Geometrical Methods.* Oxford: University Press, 1940; Reprint, New York: Dover Publications, Inc., 1963.

Craik, Alex D.D. "Calculus and Analysis in Early 19th-Century Britain: The Work of William Wallace." *Historia Mathematica* 26 (1999): 239-268.

_________. "Geometry versus Analysis in Early 19th-Century Scotland: John Leslie, William Wallace, and Thomas Carlyle." *Historia Mathematica* 27 (2000): 133-163.

Crawford, Elisabeth. *Nationalism and Internationalism in Science, 1880-1939.* Cambridge: University Press, 1992.

Cremona, Luigi. "The Fourteen-Points Conic." *Oxford, Cambridge, and Dublin Messenger of Mathematics* 3 (1866): 13-14.

_________. "On Normals to Conics, a New Treatment of the Subject." *Oxford, Cambridge, and Dublin Messenger of Mathematics* 3 (1866): 88-93.

Crilly, Tony. *Arthur Cayley, Mathematician Laureate of the Victorian Age.* To appear.

_________. "The *Cambridge Mathematical Journal* and its Descendants: 1830-1870." To appear.

_________. "The Decline of Cayley's Invariant Theory (1863-1895)." *Historia Mathematica* 15 (1988): 332-347.

_________. "The Rise of Cayley's Invariant Theory (1841-1862)." *Historia Mathematica* 13 (1986): 241-302.

_________. "The Young Arthur Cayley." *Notes and Records of the Royal Society of London* 52(1998): 267-282.

Cross, Patrick S. "The Organization of Science in Dublin from 1785 to 1835: The Men and Their Institutions." Unpublished Ph.D. diss., University of Oklahoma, 1996.

Cross, J.J. "Integral Theorems in Cambridge Mathematical Physics, 1830-1855." In *Wranglers and Physicists*, Ed. Peter M. Harman, pp. 112-148. Manchester: University Press, 1985.

Curthoys, M.C. "The Colleges in the New Era," In *The History of the University of Oxford: Nineteenth-Century Oxford, Part II*, Ed. M.G. Brock and M.C. Curthoys, pp. 115-157. Oxford: Clarendon Press, 2000.

________. "The Examination System." In *The History of the University of Oxford: Nineteenth-Century Oxford, Part I*, Ed. M.G. Brock and M.C. Curthoys, pp. 340-374. Oxford: Clarendon Press, 1997.

________. "The 'Unreformed' Colleges." In *The History of the University of Oxford: Nineteenth-Century Oxford, Part I*, Ed. M.G. Brock and M.C. Curthoys, pp. 146-173. Oxford: Clarendon Press, 1997.

Davies, Thomas Stephens. "An Analytical Discussion of Dr. Matthew Stewart's General Theorems." *Transactions of the Royal Society of Edinburgh* 15 (1844): 573-608.

________. "Analytical Investigations of Two of Dr. Stewart's General Theorems." *Cambridge and Dublin Mathematical Journal* 1 (1846): 229-238.

________. "On the Equations of Loci Traced upon the Surface of the Sphere, as Expressed by Spherical Coordinates." *Transactions of the Royal Society of Edinburgh* 12 (1833-34): 259-362.

Davies, Thomas Stephens, William Rutherford, and Stephen Fenwick. "Prospectus." *Mathematician* 1 (1843): 1-3.

"Death of Mr. Alexander Macmillan." *Nature* 53(1896): 302.

De Morgan, Augustus. *Elements of Algebra.* London: Taylor & Walton, 1837.

________. "On the Foundations of Algebra." *Transactions of the Cambridge Philosophical Society* 7 (1839): 173-187.

________. "On the Foundations of Algebra, II." *Transactions of the Cambridge Philosophical Society* 7 (1841): 237-300.

________. "On a Point Connected with the Dispute between Keill and Leibnitz about the Invention of Fluxions." *Philosophical Transactions of the Royal Society of London* 136 (1846): 107-109.

________. "On the Symbols of Logic, the Theory of the Syllogism, and In Particular of the Copula." *Transactions of the Cambridge Philosophical Society* 9 (1856): 79-127.

de Solla Price, Derek. "Toward a Model for Science Indicators." In *Toward a Metric of Science: The Advent of Science Indicators*, Ed. Yehuda Elkana *et al.*, pp. 69-95. New York: John Wiley and Sons, 1978.

Despeaux, Sloan Evans. "International Mathematical Contributions to British Scientific Journals, 1800-1900." In *Mathematics Unbound: The Evolution of an International Mathematical Community, 1800-1945*, Ed. Karen Hunger Parshall and Adrian C. Rice, pp. 61-87. Providence: American Mathematical Society and London: London Mathematical Society, 2002.

Dickson, Leonard E. "A Class of Linear Groups including the Abelian Group." *Quarterly Journal of Pure and Applied Mathematics* 31 (1900): 60-66.

________. "Concerning the Four Known Simple Linear Groups of Order 25920, with an Introduction to the Hyper-Abelian Linear Groups." *Proceedings of the London Mathematical Society* 31 (1900): 30-68.

________. "The First Hypoabelian Group Generalized." *Quarterly Journal of Pure and Applied Mathematics* 30 (1899): 1-16.

________. "Simplicity of the Abelian Group on Two Pairs of Indices in the Galois Field of Order $2n$, $n > 1$." *Quarterly Journal of Pure and Applied Mathematics* 30 (1899): 383-384.

________. "The Structure of Certain Linear Groups with Quadratic Invariants." *Proceedings of the London Mathematical Society* 30 (1899): 70-98.

________. "A Triply Infinite System of Simple Groups." *Quarterly Journal of Pure and Applied Mathematics* 29 (1898): 169-178.

Didascalus. "Female Mathematicians." *Leeds Correspondent* 3 (1819-1821): 27-33.

"Differential and Integral Calculus." *Nature* 44 (1891): 170-172.

"Drayson's 'Proper Motion of the Fixed Stars,' etc.." *Nature* 11 (1874): 66-67.

Dreyer, John L.E. "The Decade 1830-1840." In *The History of the Royal Astronomical Society 1820-1920*, Ed. John L.E. Dreyer and Herbert H. Turner, pp. 50-81.

London: Royal Astronomical Society, 1923; Reprint, Oxford: Blackwell Scientific Publications, 1987.

________. "1880-1920." In *The History of the Royal Astronomical Society 1820-1920.* In *The History of the Royal Astronomical Society 1820-1920*, Ed. John L.E. Dreyer and Herbert H. Turner, pp. 212-253. London: Royal Astronomical Society, 1923; Reprint, Oxford: Blackwell Scientific Publications, 1987.

Dubbey, John M. "Babbage, Peacock and Modern Algebra." *Historia Mathematica* 4 (1977): 295-302.

________. "The Introduction of the Differential Notation to Great Britain." *Annals of Science* 19 (1963): 38-48.

Dunbabin, J.P.D. "Finance and Property." In *The History of the University of Oxford: Nineteenth-Century Oxford, Part I*, Ed., M.G. Brock and M.C. Curthoys, pp. 375-437. Oxford: Clarendon Press, 1997.

Durand-Richard, Marie-José. "L'école algébrique anglaise et les conditions conceptuelles et institutionelles d'un calcul symbolique comme fondement de la connaissance." In *L'Europe mathématique: Histoires, Mythes, Identités*, Ed. Catherine Goldstein, Jeremy Gray, and Jim Ritter, pp. 447-477. Paris: Fondation Maison des sciences de l'homme, 1996.

Duvina, Silvina, "Le *Journal de mathématiques pures et appliquées* sous la férule de J. Liouville (1836-1874)." *Sciences et techniques en perspective* 28 (1994): 179-217.

Eccarius, Wolfgang. "August Leopold Crelle als Herausgeber des Crelleschen Journals." *Journal für reine und angewandte Mathematik* 286/287 (1976): 5-25.

Edge, David. "Quantitative Measures of Communication in Science: A Critical Review." *History of Science* 17 (1979): 103-134.

Elliott, Edwin Bailey. "On the Definition of an Invariant." *Messenger of Mathematics* 16 (1887): 5-8.

________. "On the Interchange of the Variables in Certain Linear Differential Operators (Abstract)." *Proceedings of the Royal Society of London* 46 (1889): 358-362.

________. *An Introduction to the Algebra of Quantics.* 2nd Ed. Oxford: University Press, 1913. Reprint, Bronx, NY: Chelsea Publishing Co., 1964.

Ellis, Robert Leslie. "Analytical Demonstrations of Dr. Matthew Stewart's Theorems." *Cambridge Mathematical Journal* 2 (1839-41): 271-276.

________. "Memoir of the Late D.F. Gregory, M.A., Fellow of Trinity College, Cambridge." *Cambridge Mathematical Journal* 4 (1843-45): 145-152.

________. "On Some Properties of the Parabola." *Cambridge Mathematical Journal* 1 (1837-1839): 204-207.

The Encyclopædia Britannica, 11th ed., 29 Vol. New York: The Encyclopædia Britannica Company, 1910-1911.

Engle, A.J. *From Clergyman to Don: The Rise of the Academic Profession in Nineteenth-Century Oxford.* Oxford: Clarendon Press, 1983.

________. "Emerging Concepts of the Academic Profession at Oxford 1800-1854." In *The University in Society*, Vol. 1, Ed.,, Lawrence Stone, pp. 305-352. Princeton: University Press, 1974.

Enneper, Alfred. "On the Definite Integral $\int_0^\infty \frac{\sin^q u}{u^m} du$." *Quarterly Journal of Pure and Applied Mathematics* 1 (1855): 276-279.

________. "Elementary Demonstration of an Equation Between Two Transcendental Functions." *Quarterly Journal of Pure and Applied Mathematics* 1 (1855): 272-276.

________. "On the Function $\Pi(z)$ with Imaginary and Complex Variable." *Quarterly Journal of Pure and Applied Mathematics* 1 (1855): 393-402.

________. "A General Theorem Relating to Multiple Periodic Series." *Quarterly Journal of Pure and Applied Mathematics* 1 (1855): 280-285.

Enros, Philip C. "The Analytical Society (1812-1813): Precursor of the Renewal of Cambridge Mathematics." *Historia Mathematica* 10 (1983): 26-37.

________. "Cambridge University and the Adoption of Analytics in Early Nineteenth-century England." In *Social History of Nineteenth Century Mathematics*, Ed. Herbert Mehrtens, Henk Bos, and Ivo Schneider, pp. 135-164. Boston: Birkhäuser, 1981.

Faà de Bruno, Francesco. "Invariant of the Twelfth Degree of the Quintic (a, b, c, d, e) $(x, y)^5$." *Quarterly Journal of Pure and Applied Mathematics* 4 (1855): 361-363.

Fauvel, John. "800 Years of Mathematical Traditions." In *Oxford Figures: 800 Years of the Mathematical Sciences*, Ed. John Fauvel, Raymond Flood, and Robin Wilson, pp. 1-27. Oxford: Oxford University Press, 2000.

Fenster, Della Dumbaugh, and Karen Hunger Parshall. "A Profile of the American Research Community: 1891-1906." In *The History of Modern Mathematics*, Vol. 3, Ed. Eberhard Knobloch and David E. Rowe, pp. 179-227. Boston: Academic Press, 1994.

Finkel, B. F. "Biography: W.J.C. Miller." *American Mathematical Monthly* 3 (1896): 159-163.

Forsyth, Andrew Russell. "James Whitbread Lee Glaisher." *Journal of the London Mathematical Society* 4 (1929): 101-112.

F[orsyth], A[ndrew] R[ussell]. "Obituary of Fellows Deceased." *Proceedings of the Royal Society of London* 52 (1892): xii-xiv.

Foster, Joseph. *Alumni Oxonienses: The Members of the University of Oxford, 1715-1886: Their Parentage, Birthplace, and Year of Birth, with a Record of Their Degrees.* Oxford and London: Parker and Co., 1887-1888.

Fox, Robert. "The University Museum and Oxford Science, 1850-1880." In *The History of the University of Oxford: Nineteenth-Century Oxford, Part I*, Ed. M.G. Brock and M.C. Curthoys, pp. 641-691. Oxford: Clarendon Press, 1997.

Franklin, Fabian. "Sur le Développement du Produit infini $(1-x)(1-x^2)(1-x^3)(1-x^4)\dots$" *Comptes rendus* 82 (1881): 448-450.

Fraser, Alexander Yule *et. al.*. "[O]n the Teaching of Arithmetic." *Proceedings of the Edinburgh Mathematical Society* 6 (1888): 89-102.

Frost, Percival. "On Brianchon's Hexagon." *Cambridge Mathematical Journal* 4 (1843-1845): 277-279.

Gardner, J. Helen, and Robin J. Wilson. "Thomas Archer Hirst — Mathematician Xtravagant, I-IV." *American Mathematical Monthly* 100 (1993): 435-441, 561-538, 619-625, 723- 731, 827-834, and 907-915.

Gascoigne, John. *Joseph Banks and the English Enlightenment: Useful Knowledge and Polite Culture.* Cambridge: University Press, 1994.

__________. "Mathematics and Meritocracy: The Emergence of the Cambridge Mathematical Tripos." *Social Studies of Science* 14 (1984): 547-584.

__________. *Science in the Service of Empire: Joseph Banks, the British State and the Uses of Science in the Age of Revolution.* Cambridge: University Press, 1998.

Gascoigne, Robert Mortimer. *A Historical Catalogue of Scientific Periodicals, 1665-1900.* New York: Garland Publishing, Inc., 1985.

George, Phillip. "The Scientific Movement and the Development of Chemistry in England, as Seen in the Papers Published in the *Philosophical Transactions* from 1664/5 until 1750." *Annals of Science* 8 (1952): 302-32.

Gibbon, Monk. "A Century of *Hermathena*." *Hermathena* 115 (1973): 116.

Gillispie, Charles C., Ed. *Dictionary of Scientific Biography.* 16 Vol. and 2 Supps. New York: Charles Scribner's Sons, 1970-1990.

Gispert, Hélène. "Une comparaison des journaux français et italiens dans les années 1860-1875." In *L'Europe mathématique: Histoires, Mythes, Identités,* Ed. Catherine Goldstein, Jeremy Gray, and Jim Ritter, pp. 391-406. Paris: Fondation Maison des sciences de l'homme, 1996.

_________. "The Effects of War on France's International Role in Mathematics, 1870-1914." In *Mathematics Unbound: The Evolution of an International Mathematical Community, 1800-1945,* Ed. Karen Hunger Parshall and Adrian C. Rice, pp. 105-121. Providence: American Mathematical Society and London: London Mathematical Society, 2002.

_________. *La France mathématique.* Paris: Société française d'histoire des sciences et des techinques and Société mathématique de France, 1991.

Glaisher, James W. L. "Mathematical Journals." *Nature* 22 (1880): 73-75.

_________. "The Mathematical Tripos." *Nature* 35 (1886): 199-203.

_________. "The Mathematical Tripos." *Proceedings of the London Mathematical Society* 18 (1886): 4-38.

_________. "Notes on the Early History of the Society." *Journal of the London Mathematical Society* 1 (1926): 51-64.

Gleason, Mary Louise. *The Royal Society of London: Years of Reform, 1827-1847.* Harvard Dissertations in the History of Science, Ed. Owen Gingerich. New York: Garland Publishing, Inc., 1991.

Gordan, Paul. "Beweiss, dass jede Covariante und Invariante einer binaeren Form eine ganze Function mit numerische Coefficienten einer endlichen Anzahl solchen Formen ist." *Journal für die reine und angewandte Mathematik* 69 (1868): 323-354.

Gow, Rod. "George Salmon 1819-1904." In *Creators of Mathematics: The Irish Connection*, Ed. Ken Houston, pp. 37-45. Dublin: University College Dublin Press, 2000.

________. "George Salmon 1819-1904: His Mathematical Work and Influence." *Irish Mathematical Society Bulletin* no. 39 (1997): 26-76.

Granville, Augustus Bozzi. *The Royal Society in the XIXth Century.* London: Printed for the Author, 1836.

[________.] *Science Without a Head; or The Royal Society Dissected.* London: T. Ridgway, 1830.

Grattan-Guinness, Ivor. "The Contributions of J.J. Sylvester to Mechanics and Mathematical Physics." *Notes and Records of the Royal Society of London* 44 (2001): 253-265.

________. *Convolutions in French Mathematics, 1800-1840.* 3 Vol. Basel: Birkhäuser Verlag, 1990.

________. "Mathematical Research and Instruction in Ireland, 1782-1840." In *Science in Ireland 1800-1930: Tradition and Reform*, Ed. John R. Nudds *et al.*, pp. 11-30. Dublin: Trinity College Dublin, 1988.

________. "Mathematics and Mathematical Physics from Cambridge, 1815-1840: A Survey of the Achievements and of the French Influences." In *Wranglers and Physicists*, Ed. Peter M. Harman, pp. 84-110. Manchester: University Press, 1985.

Grattan-Guinness, Ivor and W. Ledermann, "Matrix Theory," In *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences*, Ed. Ivor Grattan-Guinness. 2 Vol., 2: 775-786. London and New York: Routledge, 1994.

Graves, Charles. "Elementary Geometrical Proof of Joachimstal's Theorem." *Proceedings of the Royal Irish Academy* 5 (1853): 70-71. Also in *Journal für die reine und angewandte Mathematik* 42 (1851): 279. Also in *Nouvelles annales de mathématiques* 11 (1852): 322-323.

________. "On the Focal Circles of Plane and Spherical Conics." *Hermathena* 6 (1888): 384-396.

________. "The Ogham Alphabet." *Hermathena* 2 (1876): 443-473.

________. "On Ogham Inscriptions." *Hermathena* 6 (1888): 241-268.

_________. "On Two Fragments of a Greek Papyrus." *Hermathena* 5 (1885): 237-257.

Graves, Robert Perceval. *Life of Sir William Rowan Hamilton.* Dublin: Hodges, Figgis, & Co., 1882.

_________. "Sir W. Rowan Hamilton on the Elementary Conceptions of Mathematics." *Hermathena* 3 (1879): 469-489.

_________. "Sir William Rowan Hamilton on the Problem of Hipparchus." *Hermathena* 4 (1883): 489-506.

Gray, Jeremy. *Ideas of Space: Euclidean Non-Euclidean and Relativistic.* Clarendon Press: Oxford, 1989.

_________. "Mathematics in Cambridge and Beyond." In *Cambridge Minds*, Ed. Richard Mason, pp. 86-99. Cambridge: University Press, 1994.

_________. "Projective Geometry." In *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences*, ed. Ivor Grattan-Guinness. 2 Vol., 2: 897-907. London and New York: Routledge, 1994.

Green, George. "On the Laws of Reflection and Refraction of Light." *Transactions of the Cambridge Philosophical Society* 7 (1839): 1-24, 113-120.

_________. "On the Motion of Waves in a Variable Canal of Small Width and Depth." *Transactions of the Cambridge Philosophical Society* 6 (1838): 457-462.

_________. "Note on the Motion of Waves in Canals." *Transactions of the Cambridge Philosophical Society* 7 (1839): 87-95.

_________."On the Propagation of Light in Crystalline Media." *Transactions of the Cambridge Philosophical Society* 7 (1841): 121-140.

Gregory, Duncan. "Preface." *Cambridge Mathematical Journal* 1 (1837): 1-2.

Guicciardini, Niccolò. *The Development of Newtonian Calculus in Britain 1700-1800.* Cambridge: University Press, 1989.

Hall, A. Rupert. *The Cambridge Philosophical Society: A History, 1819-1969.* Cambridge: Cambridge Philosophical Society, 1969.

Hall, Marie Boas. *All Scientists Now: The Royal Society in the Nineteenth Century.* Cambridge: University Press, 1984.

Hamilton, William Rowan. "Theory of Systems of Rays." *Transactions of the Royal Irish Academy* 15 (1828): 69-174.

Hammond, James. "Note on an Exceptional Case in which the Fundamental Postulate of Professor Sylvester's Theory of Tamisage Fails." *Proceedings of the London Mathematical Society* 14 (1882): 82-88.

Hankins, Thomas. *Sir William Rowan Hamilton.* Baltimore, London: John Hopkins University Press, 1980.

Hannabuss, Keith. "Henry Smith." In *Oxford Figures: 800 Years of the Mathematical Sciences*, Ed. John Fauvel, Raymond Flood, and Robin Wilson, pp. 203-217. Oxford: Oxford University Press, 2000.

_________. "Mathematics." In *The History of the University of Oxford: Nineteenth-Century Oxford, Part II*, Ed. M.G. Brock and M.C. Curthoys, pp. 443-455. Oxford: Clarendon Press, 2000.

Hansen, Peter Andreas. "Extract of a Letter from Prof. Hansen to the Astronomer Royal, dated Gotha, May 31, 1859." *Monthly Notices of the Royal Astronomical Society* 19 (1859): 236-237.

_________. "From a Letter from Professor Hansen to the Astronomer Royal, dated Gotha, 1861, Feb. 2." *Monthly Notices of the Royal Astronomical Society* 21 (1861): 152-155.

Harcourt, William Vernon. "Objects and Plan of the Association." *Report of the British Association for the Advancement of Science* (1831-1832): 21-41.

Hardy, Godfrey Harold. "Dr. Glaisher and the 'Messenger of Mathematics'." *Messenger of Mathematics* 58 (1929): 159-160.

Harman, Peter M. "Edinburgh Philosophy and Cambridge Physics: the Natural Philosophy of James Clerk Maxwell," In *Wranglers and Physicists*, Ed. Peter M. Harman, pp. 84-110. Manchester: University Press, 1985.

_________. "Introduction." In *Wranglers and Physicists*, Ed. Peter M. Harman, pp. 1-11. Manchester: University Press, 1985.

Harrison, H.M. *Voyager in Time and Space: The Life of John Couch Adams.* Sussex, England: The Book Guild Ltd., 1994.

Harte, Negley. *The University of London 1836-1986.* London and Atlantic Highlands, NJ: The Athlone Press, 1986.

Harvie, Christopher. "Reform and Expansion, 1854-1871." In *The History of the University of Oxford: Nineteenth-Century Oxford, Part I*, Ed. M.G. Brock and M.C. Curthoys, pp. 698-730. Oxford: Clarendon Press, 1997.

Hawkins, Thomas. "Another Look at Cayley and the Theory of Matrices." *Archives internationales d'histoire des sciences* 26 (1977): 82-112.

Hellins, John. "A Second Appendix to the Improved Solution of a Problem in Physical Astronomy, Inserted in the Philosophical Transactions for the Year 1798, containing some further Remarks, and improved Formulæ for Computing the Coefficients A and B; by which the Arithmetical Work is Considerably Shortened and Facilitated." *Philosophical Transactions of the Royal Society of London* 90 (1800): 86-97.

Helmholtz, Hermann. "Science and Philosophy." *The Academy* 1 (1870): 128-131.

"Henry William Lloyd Tanner, 1851-1915." *Proceedings of the Royal Society of London, series A* 91 (1915): lxix-lxxiv.

Hermite, Charles. "Correspondence: Mr. Cayley and M. Hermite on Cubic Forms." *Quarterly Journal of Pure and Applied Mathematics* 1 (1855): 88-89.

________. "Extract of a Letter from M. Hermite to Professor Sylvester." *Quarterly Journal of Pure and Applied Mathematics* 1 (1855): 370-373.

________. "Mathematical Teaching at the Sorbonne 1809-1889." *Nature* 41 (1890): 597-598.

________. "Sur la théorie des fonctions homogènes à deux indéterminées." *Cambridge and Dublin Mathematical Journal* 9 (1854): 172-217.

________. "Sur les formes cubiques à deux indéterminées," *Quarterly Journal of Pure and Applied Mathematics* 1 (1855): 20-22.

Higham, John. "The Matrix of Specialization." In *The Organization of Knowledge in Modern America, 1860-1920* Ed., Alexandra Oleson and John Voss, pp. 3-18. Baltimore: The Johns Hopkins University Press, 1979.

Hill, Ian David. "Statistical Society of London-Royal Statistical Society: The First 100 Years: 1834-1934." *Journal of the Royal Statistical Society, Series A* 147 (1984): 130-139.

Hill, Micaiah John Muller. "On the Incorrectness of the Rules for Extracting the Square and Cube Roots of a Number." *Proceedings of the London Mathematical Society* 18 (1887): 171-178.

[Hirst, Thomas Archer.], "Review of *A Treatise on Conic Sections by G. Salmon.*" *Philosophical Magazine.* 4th Ser. 10 (1855): 441-442.

Holland, Charles Hepworth, Ed. *Trinity College Dublin and the Idea of a University.* Dublin: Trinity College Dublin Press, 1991.

Hoppe, Reinhold. "Determination of the Motion of Conoidal Bodies through an incompressible Fluid." *Quarterly Journal of Pure and Applied Mathematics* 1 (1855): 301-315.

Horn, D.B. *A Short History of the University of Edinburgh.* Edinburgh: University Press, 1967.

Houghton, Bernard. "Introduction: Science in the First Half of the Nineteenth Century." In *Science in the Making: Scientific Development as Chronicled by the Historic Papers in the Philosophical Magazine*, Vol. 1, Ed. E.A. Davis, pp. xxxi-xxxiii. London: Taylor & Francis, 1997.

________.*Scientific Periodicals: Their Historical Development, Characteristics and Control.* London: Clive Bingley, 1975.

Howarth, Janet. "The Self-Governing University, 1882-1914." In *The History of the University of Oxford: Nineteenth-Century Oxford, Part II*, Ed. M.G. Brock and M.C. Curthoys, pp. 599-643. Oxford: Clarendon Press, 2000.

Howarth, O.J.R. *The British Association for the Advancement of Science: A Retrospect, 1831-1931.* London: BAAS, 1931.

Howson, M.P and A.G. Black. "A Source of Much Rational Entertainment." *Mathematical Gazette* 63 (1979): 90-98.

Hutchison, Keith. "W.J.M. Rankine and the Rise of Thermodynamics." *British Journal for the History of Science* 14 (1981): 1-26.

Huxley, Leonard. *Life and Letters of Thomas Henry Huxley.* Vol. 1. London: Macmillan and Co., 1913.

"Introduction." *Oxford, Cambridge, and Dublin Messenger of Mathematics* 1 (1862): 1-4.

Ivory, James. "On the Attractions of an Extensive Class of Spheroids." *Philosophical Transactions of the Royal Society* 102 (1812): 46-82.

________. "On the Attractions of Homogeneous Ellipsoids." *Philosophical Transactions of the Royal Society* 99 (1809): 345-372.

________. "On the Expansion in a Series of the Attraction of a Spheroid." *Philosophical Transactions of the Royal Society* 112 (1822): 99-112.

________. "On the Grounds of the Method Which Laplace Has Given in the Second Chapter of the Third Book of His *Mécanique Céleste* for computing the Attractions of Spheroids of Every Description." *Philosophical Transactions of the Royal Society* 102 (1812): 1-45.

________. "Some Remarks on a Memoir by M. Poisson, Read to the Academy of Sciences at Paris, Nov. 20, 1826, and Inserted in the *Connaissance des temps* 1829." *Philosophical Magazine* n.s. 1 (1827): pp. 324-331.

"Jahrbuch Project Electronic Research Archive for Mathematics." At http://www.emis.de/MATH/JFM/JFM.html.

J.C. Poggendorff's Biographisch-Literarisches Handwörterbuch zur Geschichte der Exacten Wissenschaften. Leipzig: Johann Ambrosius Barth, 1863-1926.

Jesuiticus. "Remarks on a Paper by Mr. Moon on Fresnel's Theory of Double Refraction." *Philosophical Magazine* 3rd Ser. 28 (1846): 144-145.

Jevons, William Stanley. "Helmholtz on the Axioms of Geometry." *Nature* 6 (1871): 481-482.

"John Casey." *Proceedings of the Royal Society of London* 49 (1890-1891): xxiv-xxv.

Johnstone, P.T. "100 Not Out." *Mathematical Proceedings of the Cambridge Philosophical Society* 100 (1986): 1-4.

Kargon, Robert H. *Science in Victorian Manchester: Enterprise and Expertise.* Baltimore: The Johns Hopkins University Press, 1977.

Kelland, Philip. "Quaternions, or the Doctrine of Vectors. Elementary Illustrations." *Oxford, Cambridge and Dublin Messenger of Mathematics* 2 (1864): 136-167.

Kennedy, Alexander B.W. "On the Terminology of the Mathematical Theory of Elasticity." *Nature* 31 (1885): 304-305.

Kevles, Daniel J. *The Physicists: The History of a Scientific Community in Modern America.* Cambridge, MA: Harvard University Press, 1987.

Kirkman, Thomas P. "Applications of the Theory of the Polyedra to the Enumeration and Registration of Results." *Proceedings of the Royal Society of London* 12 (1862-1863): 341-380.

________. "Hints on the Theory of Groups." *Oxford, Cambridge, and Dublin Messenger of Mathematics* 1 (1862): 58-68.

________. "On Pluquaterions, and Homoid Products of Sums of n Squares." *Philosophical Magazine* 33 (1848): 447-459, 494-509.

________. "On the Theory of the Polyhedra." *Philosophical Transactions of the Royal Society of London* 152 (1862): pp. 121-165.

Klein, Felix, and Arnold Sommerfeld. "Mathematics of the Spinning Top." Trans. Alfred George Greenhill. *Nature* 60 (1899): 319-322, 346-349.

Kline, Morris. *Mathematical Thought from Ancient to Modern Times.* New York: Oxford University Press, 1972.

Koppelman, Elaine. "The Calculus of Operations and the Rise of Abstract Algebra." *Archive for History of Exact Sciences* 8 (1971-1972): 155-242.

Kuhn, Thomas. *The Structure of Scientific Revolutions.* 3rd Ed. Chicago and London: University of Chicago Press, 1996.

Kushner, David. "Sir George Darwin and a British School of Geophysics." *Osiris* 8 (1993): 196-224.

Lamb, Horace. "On the Deformation of an Elastic Shell." *Nature* 41 (1890): 549.

Lampe, Emil. "Das Jahrbuch über die Fortschritte der Mathematik. Rückblick und Ausblick." *Jahrbuch über die Fortschritte der Mathematik* 33 (1903): 1-5.

Leedham-Green, Elisabeth. *A Concise History of the University of Cambridge.* Cambridge: University Press, 1996.

Levett, Rawdon. "Euclid as a Text-Book." *Nature* 2 (1870): 65-66.

Leybourn, Thomas. "Advertisement." *Mathematical and Philosophical Repository n.s.*, 1 (1806).

Lilley, Samuel. "Nicholson's Journal (1797-1813)." *Annals of Science* 6 (1948): 78-101.

Liouville, Joseph. "Théorèmes de géometrie par M. Michael Roberts." *Journal de mathématiques pures et appliquées* 10 (1845): 466-468.

Love, Augustus E.H. "Alfred George Greenhill." *Journal of the London Mathematical Society* 3 (1928): 27-32.

Lubbock, John William. "On a Property of the Conic Sections." *Philosophical Magazine.* 3rd Ser. 13 (1838): 83-86.

Lützen, Jesper. *Joseph Liouville 1809-1882: Master of Pure and Applied Mathematics.* New York: Springer-Verlag, 1990.

Lyons, Sir Henry. *The Royal Society, 1660-1940.* Cambridge: University Press, 1944.

M'Cay, William S. "A Simple Method of Determining the Anharmonic Function of a Cubic." *Hermathena* 1 (1873): 261-263.

McConnell, A.J. "The Dublin Mathematical School in the First Half of the Nineteenth Century." *Proceedings of the Royal Irish Academy* 50 (1944-1945): 75-86.

MacCullagh, James. "Réclamation de priorité relativement à certaines formules pour calculer l'intensité de la lumière." *Comptes rendus* 8 (1839): 961-971.

McDowell, R. B. "The Main Narrative." In *The Royal Irish Academy: A Bicentennial History 1785-1985*, Ed. T. Ó. Raifeartaigh, pp. 1-92. Dublin: The Royal Irish Academy, 1985.

McDowell, R.B. and D.A. Webb. *Trinity College 1592-1952: An Academic History.* Cambridge: University Press: 1982.

MacFarlane, Alexànder. *Lectures on Ten British Mathematicians of the Nineteenth Century.* New York: John Wiley & Sons, 1916.

Mackay, J.S. "Notice sur le journalisme mathématique en Angleterre." *Compte rendu de l'association française pour l'avancement des science* 2 (1893): 303-308.

Mackie, J.D. *The University of Glasgow, 1451-1951.* Glasgow: Jackson, Son, & Co., 1954.

MacLeod, Roy M. "The First Issue." *Nature* 224 (1969): 440.

_________. "Macmillan and the Scientists." *Nature* 224 (1969): 428.

_________. "The New Journal." *Nature* 224 (1969): 437-439.

_________. "Private Army of Contributors." *Nature* 224 (1969): 445-449.

_________. "Retrospect: The British Association and its Historians." In *The Parliament of Science: The British Association for the Advancement of Science, 1831-1981* Roy MacLeod and Peter Collins, Ed., pp. 1-16. Middlesex, England: Science Reviews Ltd., 1981.

________. "Science in Grub Street." *Nature* 224 (1969): 423-427.

________. "Securing the Foundations." *Nature* 224 (1969): 441-444.

________. "Whigs and Savants: Reflections on the Reform Movement in the Royal Society, 1830-1848." In *Metropolis and Province*, Ed. Ian Inkster and Jack Morrell, pp. 55-90. London: Hutchinson & Co., 1983.

Malet, John Christian. "On a Class of Problems Connected With Linear Differential Equations." *Hermathena* 2 (1876): 519-521.

Marchand, Leslie Alexis. *The Athenaeum: A Mirror of Victorian Culture.* Chapel Hill: The University of North Carolina Press, 1941.

Marquis of Northampton. [Address Delivered Before the Royal Society]. *Proceedings of the Royal Society of London* 4 (1837-1843): 399-460.

Martini, Laura. "Mathematics and Politics: Shaping the Mathematical Landscape in Post-Unification Italy." *Festscrift for Laura Toti Rigatelli*, to appear.

Mathematicus. "Defense of English Periodical Mathematical Works, in Reply to Mr. Meikle." *Philosophical Magazine* 54 (1819): 367-369.

Maxwell, James Clerk. "On Faraday's Lines of Force." *Transactions of the Cambridge Philosophical Society* 10 (1858): 27-83.

Meadows, Arthur Jack. "Access to the Results of Scientific Research: Developments in Victorian Britain." In *Development of Science Publishing in Europe*, Ed. Arthur Jack Meadows, pp. 43-62. Amsterdam: Elsevier Science Publishers, 1980.

________. *Communication in Science.* London: Butterworth & Co., 1974.

________. *Science and Controversy: A Biography of Sir Norman Lockyer.* Cambridge, MA: MIT Press, 1972.

Miller, George A. "The Operation Groups of Order $8p$, p Being Any Prime Number." *Philosophical Magazine.* 5th Ser. 42 (1896): 195-200.

________. "On the Simple Isomorphisms of a Substitution-Group to Itself." *Philosophical Magazine* 5th Ser., 45 (1898): 234-242.

________. "The Substitution Groups Whose Order is Four." *Philosophical Magazine.* 5th Ser. 41 (1896): 431-437.

________. "The Transitive Substitution Groups of Order $8p$, p Being Any Prime Number." *Philosophical Magazine.* 5^{th} Ser. 43 (1897): 117-125.

Milton, Viscount: Charles William. "Address." *Report of the British Association for the Advancement of Science* 1 (1831): 15-17.

Moon, Robert. "On Fresnel's Theory of Double Refraction." *Philosophical Magazine* 3^{rd} Ser., 27 (1845): 553-559.

Morrell, J.B. "Science in the Universities: Some Reconsiderations." In *Solomon's House Revisited: The Organization and Institutionalization of Science*, Ed. Tore Frängsmyr, pp. 51-64. Canton, MA: Science History Publications, 1990.

Morrell, Jack and Arnold Thackray. *Gentlemen of Science: Early Years of the British Association for the Advancement of Science.* Oxford: Clarendon Press, 1981.

Mulcahy, John. *Principles of Modern Geometry with Numerous Applications to Plane and Spherical Figures.* Dublin: Hodges and Smith, 1862.

Nakane, Michiyo and Craig G. Fraser. "The Early History of Hamilton-Jacobi Dynamics." To appear.

Nešetřilová, Helena. "*Philosophical Magazine* a anglická mathematika v letech 1800-1850" ("*Philosophical Magazine* and English Mathematics of 1800-1850"). *Dějiny věda techniky* 7 (1974): 83-100.

Neville, E.H. "Andrew Russell Forsyth." *Journal of the London Mathematical Society* 17 (1942): 237-256.

Newcomb, Simon. "Modern Mathematical Thought." *Nature* 49 (1894): 325-329.

Nichols, James. "Preface." *Leeds Correspondent* 4 (1822).

North, John S. *The Norton History of Astronomy and Cosmology.* New York and London: W.W. Norton & Co., 1995.

________. *Waterloo Directory of English Newspapers and Periodicals 1800-1900.* 10 Vol. Waterloo: North Waterloo Academic Press, 1997.

________. *Waterloo Directory of Scottish Newspapers and Periodicals 1800-1900.* 2 Vol. Waterloo: North Waterloo Academic Press, 1989.

________. *Waterloo Directory of Irish Newspapers and Periodicals 1800-1900.* Waterloo: North Waterloo Academic Press, 1986.

"Notes." *Nature* 106 (1921): 638-639.

Novick, Peter. *That Noble Dream: The "Objectivity Question" and the American Historical Profession.* New York: Cambridge University Press, 1988.

"Obituary; Charles Eugène Delaunay." *Monthly Notices of the Royal Astronomical Society* 33 (1873): 203-209.

"Obituary; John Couch Adams." *Monthly Notices of the Royal Astronomical Society* 53 (1893): 184-209.

"Obituary Notices of Fellows Deceased." *Proceedings of the Royal Society of London* 21 (1872-1873): i-iv.

"Obituary; Peter Andreas Hansen." *Monthly Notices of the Royal Astronomical Society* 35 (1875): 168-170.

"Observations on the Subject of the Preceding Communications," *Philosophical Magazine.* 3rd Ser. 28 (1846): 145-146.

Ogilvie, Marilyn Bailey. "Caroline Herschel's Contributions to Astronomy." *Annals of Science* 32 (1975): 149-161.

"The Oxford, Cambridge and Dublin Messenger of Mathematics." *Nouvelles annales de mathématique.* 2nd Ser. 2 (1863): 191-192.

Panteki, Maria. "Relationships between Algebra, Differential Equations and Logic in England: 1800-1860." Unpublished Ph.D. dissertation, London: C.N.A.A., 1992.

Parshall, Karen Hunger. "America's First School of Mathematical Research: James Joseph Sylvester at the Johns Hopkins University, 1876-1883." *Archive for History of Exact Sciences* 38 (1988): 153-196.

_________. *James Joseph Sylvester: Life and Work in Letters.* Oxford: Clarendon Press, 1998.

_________. "Joseph H.M. Wedderburn and the Structure Theory of Algebras." *Archive for History of Exact Sciences* 32 (1985): 223-349

_________. "The Mathematical Legacy of James Joseph Sylvester." *Nieuw Archief voor Wiskunde.* 4th Ser. 17 (1999): 247-267.

_________. "The One-Hundredth Anniversary of the Death of Invariant Theory?" *The Mathematical Intelligencer* 12 (1990): 10-16.

________. "Toward a History of Nineteenth-Century Invariant Theory." In *The History of Modern Mathematics*, Ed. David E. Rowe and John McCleary, 2 Vol., 1: 157-206. San Diego: Academic Press, 1989.

Parshall, Karen Hunger and Adrian C. Rice. "The Evolution of an International Mathematical Research Community, 1800-1945: An Overview and an Agenda." In *Mathematics Unbound: The Evolution of an International Mathematical Community, 1800-1945*, Ed. Karen Hunger Parshall and Adrian C. Rice, pp. 1-15. Providence: American Mathematical Society and London: London Mathematical Society, 2002.

Parshall, Karen Hunger and David E. Rowe. *The Emergence of the American Mathematical Research Community, 1876-1900: J.J. Sylvester, Felix Klein, and E.H. Moore.* HMATH, Vol. 8. Providence: American Mathematical Society and London: London Mathematical Society, 1994.

Parshall, Karen Hunger and Eugene Seneta. "Building an International Reputation: The Case of J.J. Sylvester (1814-1897)." *American Mathematical Monthly* 104 (1997): 210-222.

Peacock, George. "Report on the Recent Progress and Present State of Certain Branches of Analysis." *BAAS Report* (1833): 185-352

________. *Treatise on Algebra.* Cambridge: J. and J.J. Deighton, 1830.

Pearson, Karl. "On the Terminology of the Mathematical Theory of Elasticity." *Nature* 31 (1885): 456-457.

Pendlebury, Charles. *Arithmetic.* 6th Ed. Cambridge. Deighton, Bell and Co., 1891.

Perl, Teri. "The Ladies' Diary or Woman's Almanack, 1704-1841." Historia Mathematica 6 (1979): 36-53.

"The Philosophical Magazine." *Endeavour*, 8 (1949): 1-2.

Picard, Émile. "Préface." In *Œuvres de Charles Hermite.* Vol. 1, pp. i-xl. Paris: Gauthier-Villars, 1905.

Pickup, W. *Leeds Correspondent* 3 (1819-1821): 254.

[Playfair, John.] "[Review:] *Traité de Méchanique Céleste.*" *Edinburgh Review* 11 (1808): 249-284.

[________.] "A Treatise on Plane and Spherical Trigonometry." *Edinburgh Review* 17 (1810): 122-135

Plücker, Julius. "Fundamental Views regarding Mechanics." *Philosophical Transactions of the Royal Society of London* 156 (1866): 361-380

________. "On a New Geometry of Space." *Philosophical Transactions of the Royal Society of London* 155 (1865): 725-791.

Poinsot, Louis. "On the Percussion of Bodies." *Philosophical Magazine* 4th Ser., 15 (1858): 161-180, 263-290, 348-359; and 4th Ser. 18 (1859): 241-259.

Pontécoulant, Comte de: Phillipe Gustave Doulcet. "Mécanique Céleste: Observations sur la comparison établie par M. Delaunay entre les expressions des coordonnées de la lune déduites de sa théorie avec celles qui avaient été obtenues antérieurement." *Monthly Notices of the Royal Astronomical Society* 23 (1863): 259-266.

________. "Sur la variation séculaire du moyen mouvement de la lune." *Monthly Notices of the Royal Astronomical Society* 19 (1859): 235-236.

Porter, Roy. "Gentlemen and Geology: The Emergence of a Scientific Career, 1660-1920." *The Historical Journal* 21 (1978): 809-836.

"Post-Office Regulations." *Philosophical Magazine.* 3rd Ser. 34 (1849): 158-159.

Pottinger, George. *Heirs of the Enlightenment: Edinburgh Reviewers and Writers 1800-1830.* Edinburgh: Scottish Academic Press, 1992.

"Preface." *Hermathena* 1 (1873): iii-iv.

[Preface]. *Memoirs of the Analytical Society* (1813): 15.

[Preface]. *Nature* 1 (20 January 1870).

"Preface." *Transactions of the Cambridge Philosophical Society* 1 (1821): pp. iii-viii.

Prescot, Bar. "Letters on the Newtonian System." *Liverpool Apollonius* no. 2 (1824): 132-186.

Prescott, John Eustace. "On the Wave Surface." *Quarterly Journal of Pure and Applied Mathematics* 2 (1857): 1-8.

Price, Bartholomew. "Address." *BAAS Report* (1860): 1-3.

Price, Michael H. *Mathematics for the Multitude.* Leicester: The Mathematical Association, 1994.

[Publishers' Notice]. *Cambridge and Dublin Mathematical Journal* 3 (1848).

Pycior, Helena M. "Early Criticism of the Symbolical Approach to Algebra." *Historia Mathematica* 9 (1982): 392-412.

_________. "George Peacock and the British Origins of Symbolical Algebra." *Historia Mathematica* 8 (1981): 23-45.

_________. "Internalism, Externalism, and Beyond: 19th-Century British Algebra." *Historia Mathematica* 11 (1984): 424-441.

Purkert, Walter and Hans Wussing. "Fundamental Concepts of Abstract Algebra." In *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences*, Ed. Ivor Grattan-Guinness. 2 Vol., 2: 741-760, London and New York: Routledge, 1994.

"Quaternions." *Nature* 9 (1873): 137-138.

Rankin, Robert A. "The First Hundred Years." *Proceedings of the Edinburgh Mathematical Society* 26 (1983): pp. 135-150.

Rankine, W.J. Macquorn. "Laws of the Elasticity of Solid Bodies." *Cambridge and Dublin Mathematical Journal* 6 (1851): 47-80.

_________. "On the Mechanical Action of Heat, Especially in Gases and Vapours." *Transactions of the Royal Society of Edinburgh* 20 (1853): 147-190.

The Record of the Royal Society, 1897. London: Harrison and Sons, 1897.

Reingold, Nathan. "Definitions and Speculations: The Professionalization of Science in America in the Nineteenth Century." In *The Pursuit of Knowledge in the Early American Republic*, Ed. Alexandra Oleson and Sanborn C. Brown, pp. 33-69. Baltimore and London: The Johns Hopkins University Press, 1976.

"Report of the Committee, Consisting of Professor Sylvester, F.R.S., and Professor Cayley, F.R.S., Appointed for the Purpose of Calculating Tables of the Fundamental Invariants of Algebraic Forms." *BAAS Report* (1879): 66.

Rice, Adrian C. "Augustus De Morgan and the Development of University Mathematics in London in the Nineteenth Century." Unpublished Ph.D. dissertation, Middlesex University, 1997.

_________. "Augustus De Morgan: Historian of Science." *History of Science* 34 (1996): 201-240.

________. "A Gradual Innovation: The Introduction of Cauchian Calculus into Mid-Nineteenth-Century Britain." *Proceedings of the Canadian Society for the History and Philosophy of Mathematics* 13 (2000): 48-63.

________. "Mathematics in the Metropolis: A Survey of Victorian London." *Historia Mathematica* 23 (1996): 376-417.

________. "Review of *Messengers of Mathematics: European Journals (1800-1946)*." *Historia Mathematica* 25 (1998): 326-331.

Rice, Adrian C. and Robin J. Wilson. "From National to International Society: The London Mathematical Society, 1867-1900." *Historia Mathematica* 25 (1998): 185-217.

Rice, Adrian C., Robin J. Wilson, and J. Helen Gardner. "From Student Club to National Society: The Founding of the London Mathematical Society in 1865." *Historia Mathematica* 22 (1995): 402-421.

Richards, Joan L. "The Art and Science of British Algebra: A Study in the Perception of Mathematical Truth." *Historia Mathematica* 7 (1980): 343-365.

________. *Mathematical Visions: The Pursuit of Geometry in Victorian England.* Boston: Academic Press, Inc., 1988.

Riemann, Bernhard. "On the Hypotheses Which Lie at the Bases of Geometry." Trans. William Kingdon Clifford. *Nature* 8(1873): 14-17, 36-37.

Roberts, David L. "Albert Harry Wheeler (1873-1950): A Case Study in the Stratification of American Mathematical Activity." *Historia Mathematica* 23 (1996): 269-287.

Robertson, Abra[ha]m. "Demonstrations of the Late Dr. Maskelyne's Formulae for Finding the Longitude and Latitude of a Celestial Object from Its Right Ascension and Declination; And for Finding Its Right Ascension and Declination from Its Longitude and Latitude, the Obliquity of the Ecliptic Being Given in Both Cases." *Philosophical Transactions of the Royal Society of London* 106 (1816): 138-148.

________. "Direct and Expeditious Methods of Calculating the Excentric from the Mean Anomaly of a Planet." *Philosophical Transactions of the Royal Society of London* 106 (1816): 127-137.

________. "On the Precession of the Equinoxes." *Philosophical Transactions of the Royal Society of London* 97 (1807): 57-82.

Ross, Dorothy. *The Origins of American Social Science.* New York: Cambridge University Press, 1991.

Rothblatt, Sheldon. *The Revolution of the Dons: Cambridge and Society in Victorian England.* New York: Basic Books, Inc., 1968.

Royal Society of Edinburgh: Index of Fellows Elected 1783 to 1883. Edinburgh: Scotland's Cultural Heritage, 1984.

Russell, W.H.L. "Report on Recent Progress in Elliptic and Hyperelliptic Functions." *BAAS Report* (1869): 335-360; (1872): 334-359; (1873): 307-345.

Rutherford, William, and Stephen Fenwick. "Preface." *Mathematician* 3 (1850).

Salmon, George. *Lessons Introductory to the Modern Higher Algebra.* 5th Ed. Dublin: Hodges, Figgis & Co., 1885. Reprint, Bronx, NY: Chelsea Publishing Co., 1964.

_________. "On the Number of Normals which Can Be Drawn From a Given Point to a Given Surface." *Cambridge and Dublin Mathematical Journal* 3 (1848): 46-47.

_________. "On the Properties of Surfaces of the Second Degree which Correspond to the Theorems of Pascal and Brianchon on Conic Sections." *Philosophical Magazine* 3rd Ser. 24 (1844): 49-51.

Sampson, Ralph Allen. "The Decade 1840-1850." In *The History of the Royal Astronomical Society 1820-1920*, Ed. John L.E. Dreyer and Herbert H. Turner, pp. 82-109. London: Royal Astronomical Society, 1923; Reprint, Oxford: Blackwell Scientific Publications, 1987.

"Samuel Roberts, 1827-1913." *Proceedings of the London Mathematical Society.* Ser. A. 89 (1914): xx-xxi.

Schläfli, Ludwig. "On the Distribution of Surfaces of the Third Order into Species, in Reference to the Absence or Presence of Singular Points, and the Reality of Their Lines." *Philosophical Transactions of the Royal Society of London* 153 (1863): 193-241.

Schlissel, Arthur. "The Development of Asymptotic Solutions to Linear Ordinary Differential Equations." *Archive for the History of Exact Sciences* 16 (1976-1977): 307-378.

Siegmund-Schultze, Reinhard. " 'Scientific Control' in Mathematical Reviewing and German—U.S.-American Relations between the Two World Wars." *Historia Mathematica* 21 (1994): 306-329.

Shapin, Steven. "Discipline and Bounding: The History and Sociology of Science as Seen Through the Externalism-Internalism Debate." *History of Science* 30 (1992): 333-369.

Shapin, Steven and Arnold Thackray. "Prosopography as a Research Tool in History of Science: The British Scientific Community 1700-1900." *History of Science* 12 (1974): 1-28.

Simpson, Renate. *How the PhD Came to Britain: A Century of Struggle for Postgraduate Education.* Surrey, UK: The Society for Research into Higher Education, 1983.

Small, Henry G. "The Lives of a Scientific Paper." In *Selectivity in Information Systems: Survival of the Fittest*, Ed. Kenneth S. Warren, pp. 83-97. New York: Praeger Science Publishers, 1985.

Smith, Crosbie. "'Mechanical Philosophy' and the Emergence of Physics in Britain: 1800-1850." *Annals of Science* 33 (1976): 3-29.

Smith, Crosbie and M. Norton Wise. *Energy and Empire: A Biographical Study of Lord Kelvin.* Cambridge: University Press, 1989.

Smith, G.C. *The Boole - De Morgan Correspondence, 1842-1864.* Oxford: Clarendon Press, 1982.

Smith, H[enry].J. Stephen."On the Present State and Prospects of Some Branches of Pure Mathematics." *Proceedings of the London Mathematical Society* 8 (1876-1877): 6-27.

_________. "Report on the Theory of Numbers." *BAAS Report* 28 (1859): 228-267; 29 (1860): 120-172; 30 (1861): 292-340; 31 (1862): 503-526; 32 (1863): 768-786; and 34 (1865): 322-374.

_________. *Report on the Theory of Numbers.* 1894; Reprint, New York: Chelsea Publishing Co., 1965.

Smith, Robert W. "The Cambridge Network in Action: The Discovery of Neptune." *Isis* 80 (1989): 395-422.

"Solutions of Problems." *Cambridge Mathematical Journal* 3 (1841-1843): 95, 152, 292.

"Solutions of Problems in the Senate-House Papers." *Cambridge Mathematical Journal* 1 (1837-1839): 32-34, 95, 144, 282.

"Solutions of Senate-House Problems." *Cambridge Mathematical Journal* 2 (1839-1841): 94-96, 142-144.

Spearman, T.D. "Four Hundred Years of Mathematics." In *Trinity College Dublin and the Idea of a University* Ed. Charles Hepworth Holland, pp. 280-293. Dublin: Trinity College Dublin Press, 1991.

________. "James MacCullagh." In *Science in Ireland 1800-1930: Tradition and Reform*, Ed. John R. Nudds *et. al.*, pp. 41-60. Dublin: Trinity College Dublin, 1988.

________. "Mathematics and Theoretical Physics." In *The Royal Irish Academy: A Bicentennial History*, Ed. T. Ó Raifeartaigh, pp. 201-239. Dublin: The Royal Irish Academy, 1985.

Spottiswoode, William. "Researches on the Theory of Invariants." *Proceedings of the Royal Society of London* 7 (1854-1855): 204-207.

Steiner, Jakob. "On Certain Geometrical Theorems." *Cambridge and Dublin Mathematical Journal* 6 (1851): 160-167.

________. "On Two New Methods of Defining Curves of the Second Order, Together with New Properties of the Same Deducible Therefrom." *Cambridge and Dublin Mathematical Journal* 8 (1853): 227-249.

[Stephen, Leslie.] *Sketches from Cambridge by a Don.* London: Oxford University Press, 1932.

Stephen, Sir Leslie, and Sir Sidney Lee, Ed. *The Dictionary of National Biography.* London: Oxford University Press, 1885-1901.

Stokes, George Gabriel. "On Attractions, and on Clairaut's Theorem." *Cambridge and Dublin Mathematical Journal* 4 (1849): 194-219.

________. "On the Critical Values of the Sums of Periodic Series." *Transactions of the Cambridge Philosophical Society* 8 (1848): 533-585.

________. "On the Dynamical Equations." *Cambridge and Dublin Mathematical Journal* 3 (1848): 121-127.

________. "Notes on Hydrodynamics IV: Demonstration of a Fundamental Theorem." *Cambridge and Dublin Mathematical Journal* 3 (1848): 209-219

________. "Notes on Hydrodynamics VI: On Waves." *Cambridge and Dublin Mathematical Journal* 4 (1849): 219-240 on pp. 219-220.

________. "Report on Recent Researches in Hydrodynamics." *BAAS Report* (1846): 1-19.

________. "On the Theories of the Internal Friction of Fluids in Motion, and of the Equilibrium and Motion of Elastic Solids." *Transactions of the Cambridge Philosophical Society* 8 (1847): 287-319.

________. "On the Variation of Gravity at the Surface of the Earth." *Transactions of the Cambridge Philosophical Society* 8(1849): 672-695.

Stone, Lawrence. "Prosopography." *Daedalus* 100 (1971): 46-79.

________. "The Size and Composition of the Oxford Student Body 1580-1910." In *The University in Society*, Vol. 1, Ed. Lawrence Stone, pp. 3-110. Princeton: University Press, 1974.

Sturm, Rudolf. "On Correlative Pencils." *Proceedings of the London Mathematical Society* 7 (1876): 175-194.

Sviedrys, Romualdas. "The Rise of Physical Science at Victorian Cambridge." *Historical Studies in the Physical Sciences* 2 (1970): 127-151.

Sussex, Duke of. "Address Delivered before the Royal Society." *Abstracts of the Papers Printed in the Philosophical Transactions of the Royal Society of London* 3 (1830-1837): 140-155.

Swale, J.H. "Advertisement." *Liverpool Apollonius* no. 1 (1823).

________. "To Correspondents &c." *Liverpool Apollonius* no. 2 (1824).

________. [Dedication] *Liverpool Apollonius* no. 1 (1823).

________. *Liverpool Apollonius* no. 2 (1824): 51-52.

Sylvester, James Joseph. "Additions to the Articles, 'On a New Class of Theorems,' and 'On Pascal's Theorem'." *Philosophical Magazine* 37 (1850): 363-370.

________. "Algebraical Researches, Containing a Disquisition on Newton's Rule for the Discovery of Imaginary Roots, and an Allied Rule Applicable to a Particular Class of Equations, together with a Complete Invariantive Determination of the Character of the Roots of the General Equations of the Fifth Degree, &c." *Philosophical Transactions of the Royal Society of London* 154 (1864): 579-666.

________. "Astronomical Proclusions: Commencing with an Instantaneous Proof of Lambert's and Euler's Theorems, and Modulating Through a Construction of the Orbit of a Heavenly Body from Two Heliocentric Distances, the Subtended Chord, and the Periodic Time, and the Focal Theory of Cartesion Ovals, into a Discussion of Motion in a Circle and its Relation to Planetary Motion." *Philosophical Magazine.* 4th Ser. 31 (1866): 52-76.

_________. *The Collected Mathematical Papers of James Joseph Sylvester.* Ed. Henry Frederick Baker. 4 Vol. Cambridge: University Press, 1904, 1908, 1909, 1912. Reprint, New York: Chelsea Publishing Co., 1973.

_________."On the Complete System of the 'Grundformen' of the Binary Quantic of the Ninth Order." *American Journal of Mathematics* 2 (1879): 98-99.

_________. "On an Elementary Proof and Generalization of Sir Isaac Newton's Hitherto Undemonstrated Rule for the Discovery of Imaginary Roots." *Proceedings of the London Mathematical Society* 1 (1865-66): 1-16.

_________. "An Enumeration of the Contacts of Lines and Surfaces of the Second Order." *Philosophical Magazine.* 4th Ser. 1 (1851): 119-140.

_________."An Instantaneous Demonstration of Pascal's Theorem by the Method of Indeterminate Coordinates." *Philosophical Magazine* 37 (1850): 212.

_________. "On a Linear Method of Eliminating between Double, *Treble*, and Other Systems of Algebraic Equations." *Philosophical Magazine* 18 (1841): 425-435.

_________. "The Motion of a Free Rotating Body." *Nature* 1 (1870): 482.

_________. "On the Motion of a Rigid Body acted on by no External Forces." *Philosophical Transactions of the Royal Society of London* 156 (1866): 757-780.

_________. "On a New Class of Theorems in Elimination between Quadratic Functions," *Philosophical Magazine.* 3rd Ser. 37 (1850): 363-370.

_________. "Observations sur un article de M. Poulain." *Les Mondes* 11 (1866): 435-437.

_________. "Rotation of a Rigid Body." *Nature* 1 (1870): 532.

_________. "Sketch of a Memoir on Elimination, Transformation, and Canonical Forms." *Cambridge and Dublin Mathematical Journal* 6 (1851): 192-193.

_________. "On Subinvariants, That Is, Semi-Invariants to Binary Quantics of an Unlimited Order." *American Journal of Mathematics* 5 (1882): 79-136.

_________. "Sur une extension de la théorie des équations algébriques." *Comptes rendus* 58 (1864): 689-691.

_________. "Sur une propriété nouvelle de l'équation qui sert à detérminer les inégalités séculaires des planètes." *Nouvelles annales de mathématiques* 11 (1852): 434-440.

_________. "Tables of the Generating Functions and Groundforms for the Binary Quantics of the First Ten Orders." *American Journal of Mathematics* 2 (1879): 223-251.

Sylvester, James Joseph, Arthur Cayley, George Gabriel Stokes, Norman Macleod Ferrers, and Charles Hermite. "Address to the Reader." *Quarterly Journal of Pure and Applied Mathematics* 1 (1855): i-ii.

Tait, Peter Guthrie. "Memoir." In W.J. Macquorn Rankine, *Miscellaneous Scientific Papers*, Ed. W.J. Millar, pp. xix-xxxvi. London: Charles Griffin & Co., 1881.

_________. "Quaternions." *Oxford, Cambridge and Dublin Messenger of Mathematics* 1 (1862): 78-91, 140-156, 203-219.

"*La Théorie Hugodécimale; ou, La Base scientific et définitive de l'Arithmologistique universelle.* Par le Cte. Léopold Hugo (Paris 1877)." *Nature* 16 (1877): 359.

Thompson, Silvanus P. *The Life of William Thomson, Baron Kelvin of Largs.* Vol. 1. London: Macmillan and Co., 1910.

Thomson, William. [Editor's Note]. *Cambridge and Dublin Mathematical Journal* 3 (1848): 67.

_________. "On the Dynamical Theory of Heat." *Transactions of the Royal Society of Edinburgh* 20 (1853): 261-289

_________. "Notes on Hydrodynamics I: On the Equation of Continuty." *Cambridge and Dublin Mathematical Journal* 2 (1847): 282-286.

_________. "Notes on Hydrodynamics II: On the Equation of the Bounding Surface." *Cambridge and Dublin Mathematical Journal* 3 (1848): 89-93.

_________. "Notes on Hydrodynamics V: On the Vis-Viva of a Liquid in Motion." *Cambridge and Dublin Mathematical Journal* 4 (1849): 90-95.

[Title page.] *Oxford, Cambridge, and Dublin Messenger of Mathematics* 1 (1862).

Todhunter, Issac. *History of the Theories of Attraction and the Figure of the Earth.* 2 Vol. London: Macmillan and Co., 1873.

Toplis, John. "On the Decline of Mathematical Studies, and the Sciences Dependent on Them." *Philosophical Magazine* 20 (1805): 25-31.

Townsend, Richard. "On the Problem to Determine in Magnitude, Position, and Figure, the Surface of the Second Order which Passes through Nine Given Points." *Cambridge and Dublin Mathematical Journal* 4 (1849): 241-252.

_________. "On a Theorem in Confocal Surfaces of the Second Order." *Cambridge and Dublin Mathematical Journal* 5 (1850): 177-178.

Tucker, Robert. "Euclid as a Text-Book." *Nature* 1 (1870): 534.

_________. "Prof. Clifford's Mathematical Papers." *Nature* 20 (1879): 195.

Turner, Herbert H. "The Decade 1820-1830." In *The History of the Royal Astronomical Society 1820-1920*, Ed. John L.E. Dreyer, Herbert H. Turner, pp. 1-50. London: Royal Astronomical Society, 1923. Reprint, Oxford: Blackwell Scientific Publications, 1987.

Vann, J. Don, and Rosemary T. VanArsdel, Ed. *Victorian Periodicals: A Guide to Research.* New York: Modern Language Association of America: 1978.

Venn, John. *Alumni Cantabrigienses; A Biographical List of All Known Students, Graduates and Holders of Office at the University of Cambridge.* Cambridge: University Press, 1922-54.

"Vorrede." *Jahrbuch über die Fortschritte der Mathematik* 1 (1871): i-iv.

Wagner-Döbler, Roland and Jan Berg. "Nineteenth-Century Mathematics in the Mirror of Its Literature: A Quantitative Approach." *Historia Mathematica* 23 (1996): 288-318.

Wallis, Ruth, and Peter Wallis. "Female Philomaths." *Historia Mathematica* 7 (1980): 57-64.

Wallis, Peter, Ruth Wallis, Peter Ransom, and John Fauvel. *Mathematical Tradition in the North of England.* Durham: NEBMA, 1991.

Walsh, W.H. "The Zenith of Greats." In *The History of the University of Oxford: Nineteenth-Century Oxford, Part II*, Ed. M.G. Brock and M.C. Curthoys, pp. 311-326. Oxford: Clarendon Press, 2000.

Walton, William. "On Brianchon's Hexagon." *Cambridge Mathematical Journal* 4 (1843-1845): 163-167.

Weddle, Thomas. "Demonstration of Pascal's Hexagramme." *Cambridge and Dublin Mathematical Journal* 3 (1848): 285-286.

________. "On the Different Published Demonstrations of 'Pascal's Hexagramme'." *Cambridge and Dublin Mathematical Journal* 4 (1849): 284-285.

________. "Investigation of Certain Properties of the Ellipsoid." *Cambridge and Dublin Mathematical Journal* 2 (1847): 13-18.

________. "On the Theorems of Space Analogous to Those of Pascal and Brianchon in a Plane." *Cambridge and Dublin Mathematical Journal* 4 (1849): 26-55; 5 (1850): 58-69; and 6 (1851): 114-135.

Whewell, William. "On the Empirical Laws of the Tides in the Port of London; With Some Reflexions on the Theory." *Philosophical Transactions of the Royal Society of London* 124 (1834): 15-45.

________."Essay towards a First Approximation to a Map of Cotidal Lines." *Philosophical Transactions of the Royal Society of London* 123 (1833): 147-236.

________. "Report on the Recent Progress and Present Condition of the Mathematical Theories of Electricity, Magnetism, and Heat." *BAAS Report* (1835): 1-34.

________. "Researches on the Tides. Fifth Series. On the Solar Inequality and on the Diurnal Inequality of the Tides at Liverpool." *Philosophical Transactions of the Royal Society of London* 126 (1836): 131-148.

________. "Researches on the Tides. Fourth Series. On the Empirical Laws of the Tides in the Port of Liverpool." *Philosophical Transactions of the Royal Society of London* 126 (1835): 1-16.

________. "Researches on the Tides. Twelfth Series. On the Laws of the Rise and Fall of the Sea's Surface during Each Tide." *Philosophical Transactions of the Royal Society of London* 130 (1840): 255-272.

Who Was Who, a Companion to Who's Who, Containing the Biographies of Those who Died. London, A. & C. Black: 1897-1995.

Wilkinson, Benjamin. "On Integration by Rationalization." *Hermathena* 1 (1873-1874): 254-260.

_________. "The Properties of the Cartesian Oval Treated Geometrically." *Hermathena* 2 (1876): 509-518.

Wilkinson, Thomas Turner. 'The Lancashire Geometers and Their Writings." *Memoirs of the Literary and Philosophical Society of Manchester* 11 (1854): 123-157.

_________. "Mathematical Periodicals." *Mechanics Magazine*, 48 (1848): 56-57, 203-204; 49 (1848):5-7, 203-204, 303-306; 58 (1853): 306-307, 327-328,.

"William Burnside — 1852-1927." *Proceedings of the Royal Society of London* Ser. A, 117 (1928): xi-xxv.

"William James Lewis — 1847-1926." *Proceedings of the Royal Society of London* Ser. A 111 (1926): xliv-xlviii.

Wilson, C. "The Three-Body Problem." In *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences.* Ed. Ivor Grattan-Guinness. 2 Vol., 2: 1054-1061. London and New York: Routledge, 1994.

Wilson, David B. "The Educational Matrix: Physics Education at Early-Victorian Cambridge, Edinburgh and Glasgow Universities." In *Wranglers and Physicists*, Ed., Peter M. Harman, pp. 12-48. Manchester: University Press, 1985.

Wilson, David B., Ed. *The Correspondence Between Sir George Gabriel Stokes and Sir William Thomson, Baron Kelvin of Largs.* 2 Vol. Cambridge: University Press, 1990.

Wilson, James M. "The Early History of the Association." *Mathematical Gazette* 10 (1921): 239-246.

Winstanley, Denys A. *Early Victorian Cambridge.* Cambridge: University Press, 1940. Reprint, New York: Arno Press, 1977.

Woodhouse, Robert. "On the Independence of Analytical and Geometrical Investigation and on the Advantages to be Derived from their Separation." *Philosophical Transactions of the Royal Society of London* 92 (1802): 85-125.

_________."On the Necessary Truth of Certain Conclusions Obtained by Means of Imaginary Expressions." *Philosophical Transactions of the Royal Society of London* 91 (1801), 78-119.

_________.*The Principles of Analytical Calculuation.* Cambridge: University Press, 1803.