Another difficult problem faced by a translator concerns which modern words to use in the translation. Here the difficulty is caused by the evolving interpretation of words commonly used in the probability literature. How should early concepts of the probability calculus, expressed in late 17th- or early 18th-century Latin, be rendered into English when some 21st-century uses of probabilistic words differ from their original meaning? To address this problem, Sylla has chosen consistently to render, for example, the Latin phrase *aequa sorte* as “with equal lot” where others might translate it as “with equal probability” or “with equal likelihood.” The latter phrases come with 300 years of interpretative baggage; the word “lot,” on the other hand, is rarely used in this sense and maintains the original meaning. Initially, I found this approach, especially with “lot,” archaic and jarring. But that was perhaps intentional, since each time the phrase is encountered it reminds the reader that the approach to probability theory at its birth was different from what it is now in adulthood. For those who have a problem with some of Sylla’s word choices, it would be useful to photocopy her explanation of the translation of some key words on pp. 113–123 and refer to it as you read through Bernoulli’s text.

Clearly written for historians of mathematics, Sylla’s translation and commentary is an excellent read and should immediately be seen as a valuable resource for those interested in the history of probability.

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Arthur Cayley: Mathematician Laureate of the Victorian Age

James Joseph Sylvester: Jewish Mathematician in a Victorian World

It is 70 years since Eric Temple Bell christened Cayley and Sylvester the “Invariant Twins” in his well-known book *Men of Mathematics* [Bell, 1937]. This popular work, though frequently criticized by historians of mathematics for its opinionated writing and lack of historical accuracy, undoubtedly did more than any other book of the 20th century to introduce the varied personalities of our subject to a general mathematical readership. In particular, Bell’s chapter on the Invariant Twins chronicles the lives and mathematical achievements of these two men, asserting that

The lives of Cayley and Sylvester should be written simultaneously, if that were possible. Each is a perfect foil to the other, and the life of each, in large measure, supplies what is lacking in the other. Cayley’s life was serene; Sylvester, as he himself bitterly remarks, spent much of his spirit and energy “fighting the world.” Sylvester’s thought was at times as turbulent as a millrace; Cayley’s was always strong, steady, and unruffled. . . . Yet these two became close friends and inspired one another to some of the best work that either of them did. [Bell, 1937, 379]
Bell’s chapter is indeed informative and entertaining, but descends at times into caricature, while also containing a number of inaccuracies and misunderstandings. It is unfortunate, therefore, that so much time has elapsed before the appearance of detailed and accurate biographies of Cayley and Sylvester, and that the traditional myths about these two mathematicians have been allowed to circulate for so long.

It is, moreover, a remarkable coincidence that their authors, after many years of painstaking historical research, should have completed their lengthy accounts around the same time, and that these biographies, written in broadly similar styles, should have been issued by the same publisher in the same year. True, their authors have frequently written articles and given lectures about their subjects in recent years, and Karen Parshall produced a useful book of Sylvester’s correspondence in 1998 [Parshall, 1998], but these two biographies are indeed long overdue and are greatly to be welcomed.

Of the two men, James Joseph Sylvester was undoubtedly the more temperament, but probably not to the extent claimed by Bell. Parshall describes a fascinating but complex character who was “humorous in his false self-deprecation,” “colorful and genuine in his gratitude,” and though “passionate in his beliefs and in his sense of injustice,” had “a spirit of generosity” (pp. 3–4). He could indeed be absent-minded, fiery-tempered, and eccentric, but he was so much more than this.

Born in 1814, Sylvester showed early promise of mathematical ability, attending mathematics classes given by Augustus De Morgan at University College London, at the age of 14. Although he was not an Orthodox Jew, his faith was vitally important to him, and in his early life he was subjected to insults and prejudice. Although permitted to study at Cambridge University and sit the examinations, he could not receive his degree, as he was not prepared to sign the 39 articles of the Church of England. (His Cambridge degree was awarded to him many years later, in 1872, once the rules had been changed.) Moreover, in spite of his being placed second wrangler in the Cambridge Tripos examination, his religion prevented him from being allowed to pursue a fellowship at either of the ancient universities.

But Sylvester desired an academic career that would enable him to carry out the mathematical researches that were so dear to him. He was able to obtain a professorship of natural philosophy at University College London, and subsequently a post at the University of Virginia, but neither appointment proved satisfactory, for different reasons, and in the mid-1840s he found himself back in London with no academic position. He became an actuary, and later secretary, at the Equity and Law Life Assurance Society, staying there for ten years, and it was during his time there that he met Arthur Cayley. In spite of their different personalities they became firm friends, sharing their mathematical ideas and pioneering what would eventually be known as the theory of invariants.

In 1855 Sylvester was appointed to an academic post, professor of mathematics at the Royal Military Academy at Woolwich. Here he hoped to be able to develop his mathematical research interests, but found that no one else was interested in his enthusiasms and that too much of his time was taken up with routine teaching. At the age of 55, new military regulations forced him to retire, and he spent his time pursuing his other interests, such as the writing of poetry.

Sylvester’s days of regular employment seemed to be over. But in 1876 a new career started when he was head-hunted by Daniel Coit Gilman to become the first professor of mathematics at the newly founded Johns Hopkins University in Baltimore. This was the ideal position for him, and he spent a happy and productive seven years there, working on his own research, training others to be professional mathematicians, and building up a research school of a type known in continental Europe but previously unknown in the United States. As part of this process he founded, edited, and contributed to a new publication, the *American Journal of Mathematics*, which continues to this day.

In 1883, at the age of 69, Sylvester returned to England to embark on his final career move. By this time, the religious strictures at Oxford and Cambridge had been removed, and he was appointed Savilian Professor of Geometry at Oxford University, in succession to Henry Smith, who had died unexpectedly. But if he hoped to engender the same research atmosphere in Oxford as he had at Johns Hopkins, he was to be sorely disappointed. Oxford was still primarily a teaching institution, and as his eyesight increasingly failed him, he was forced to move back to London, where he died in 1897. Summarizing the life of Sylvester, Parshall concludes:

Sylvester the Victorian, Sylvester the Jew, Sylvester the mathematician—these were not three separate entities to be understood in three distinct ways. They were one man who, simultaneously shaped by his religion, his time, and his place, crafted a life for himself as a mathematician in the Victorian era while laying foundations—both mathematical and professional—upon which others would later build. (p. 7)
In contrast, Arthur Cayley’s personality seems to have been rather more straightforward and of less interest, but Tony Crilly has been largely successful in his attempts to bring him to life. Born the son of a “Russia merchant” in 1821, the young Cayley spent his early years in St. Petersburg before returning to England at the age of 8, where he soon developed a remarkable ability for mathematics. He enrolled as a day pupil at King’s College London at the age of 14, and progressed from there to Trinity College, Cambridge, where he enjoyed “as glittering an undergraduate academic career as any student at Cambridge during the nineteenth century” (p. 27), becoming senior wrangler and winner of the coveted Smith’s prize in mathematics.

With such a spectacular undergraduate career behind him, he was naturally awarded a fellowship at Trinity College, but as with Sylvester, the religious rules at Cambridge affected his future career. In those days, you could become a college fellow only if you were prepared to train for the priesthood, and Cayley, while happy to have signed the 39 articles, was not interested in going down this path. He left Trinity to go to Gray’s Inn and proceed to the Bar, becoming a respected and successful London lawyer. Shortly after arriving in London he met Sylvester, and thus began their remarkable friendship and mathematical collaboration. During his 17 years in London, Cayley wrote no fewer than 200 mathematical papers in his spare time, including some of his most important contributions to the subject.

In 1863 Cambridge founded a new professorship, the Sadleirian Chair of Pure Mathematics, at Trinity College. There was no accompanying religious requirement, and Cayley was duly appointed and returned to his alma mater. Here he spent the rest of his life, carrying out research on a wide range of topics—algebra, geometry, combinatorial mathematics (in particular, the study and enumeration of trees and chemical molecules and the four-color problem) and, of course, invariant theory. He also visited the United States for six months in 1882 to be with Sylvester in Baltimore. One of the most prolific mathematical researchers of all time, Cayley produced research papers at a remarkable rate, though he seems not to have been an inspiring teacher. He died in Cambridge in 1895.

Comparing the lives and achievements of Cayley and Sylvester, as portrayed in these two books, is a fascinating enterprise. The two men were similar in many ways. Both were mathematically gifted from an early age, their talents being recognized by their parents, who arranged for them to attend classes in the colleges of London University before proceeding to Cambridge to study for a degree. Both fell foul of the religious rules there, returning to London, where they spent all their spare time on mathematics and worked on similar problems in combinatorics and algebra. Both were pioneers of invariant theory. Both applied their combinatorial work on trees to topics in chemistry. Both were supportive of women’s education, with Cayley trying to influence the powers-that-be at Cambridge to accept women, and Sylvester teaching mathematics to Florence Nightingale in London and Christine Ladd in Baltimore. Both became presidents of Section A (Mathematics and Physics) of the British Association. Both were strong supporters of the London Mathematical Society at the time of its foundation in 1865, presenting papers in its first year. Both became presidents of this Society, and both were awarded its most senior prize, the De Morgan Medal. In addition, both enjoyed reading literature in their spare time, particularly that of the classical writers.

However, in many other ways they seemed very different. Although reference has already been made to Sylvester’s fiery temperament and Cayley’s calming influence, Sylvester could also be placid, while Cayley occasionally became passionate when roused. Sylvester seemed at times somewhat eccentric, while Cayley seemed relatively straightforward. Sylvester’s mathematical interests were largely in algebra, number theory, and combinatorics, while Cayley’s were much more wide-ranging, extending also to topics in applied mathematics and astronomy. Sylvester was successful in creating a research school in Baltimore (though not in Oxford), while Cayley was unable to do likewise in Cambridge. Cayley published incessantly and his collected works fill 13 volumes, while Sylvester was often reluctant to write up his work and his collected papers run to only four volumes. Cayley seems to have been little interested in teaching and was a rather uninspiring teacher, while Sylvester was excited by certain educational issues, such as the desire to communicate mathematics to the general public and the movement to replace Euclid’s Elements by alternative geometrical texts. Cayley enjoyed mountain climbing, while Sylvester preferred the more homely activities of singing and writing poetry.

Not surprisingly, the contents of these two biographies share many common features. Each is a well-written and thorough account of its subject, set in the context of the places in which he lived, the situations in which he found himself, and the people that surrounded him. Each book opens with an incident in the life of its subject before embarking on the traditional chronological approach. The Sylvester biography is generally more focused than the Cayley one, being 150 pages shorter and with a more exciting and wide-ranging story to tell; indeed, in reading the Cayley
biography one is occasionally tempted to sympathize with one of his contemporaries who wrote, “Story, God bless you, there is none to tell, Sir” (p. xiv). Both books contain a wealth of useful and well-researched information that is difficult to find elsewhere. As sources for what was happening in the academic worlds in which their subjects lived and worked, both authors do a first-rate job and the results are to be warmly welcomed.

Each biography is also liberally supplied with back-up reference material, with over 100 pages of detailed notes and bibliographical information and a substantial index. Parshall includes an interesting epilogue, while Crilly has a helpful chronology of Cayley’s life and an informative list of members of “Arthur Cayley’s Social Circle” (which includes, somewhat bizarrely, E.T. Bell, Einstein, Hardy, and Ramanujan). Both books include several photographs and other pictures, the Cayley biography rather more than the Sylvester one; it is unfortunate that in each book the publishers chose to collect these together in one or two sections rather than spread them out throughout the book where they would have made more sense.

As both authors will have realized while writing their respective works, it is always difficult to decide how much technical mathematics to include in a mathematical biography: too much detail can make the text indigestible, while too little can give an inadequate treatment of the person being portrayed. Parshall chooses to present rather more mathematical explanation in the text than Crilly, whereas Crilly includes a valuable glossary of mathematical terms. Given that most readers wishing to know about Cayley and Sylvester are likely to be pure mathematicians, it seems that both books probably include too little mathematical detail. An optional few pages at the end of each chapter developing the relevant mathematical ideas would have been most helpful, without interrupting the flow of the text.

Both biographies have been well researched, but in books of this size it is inevitable that mistakes occur. In particular, Parshall misunderstands the nature of Alfred Kempe’s errors in his four-color problem paper of 1879, and writes “Haken” (of Appel and Haken fame) as “Hacken.” Her discussion of the changing relationship between Sylvester and Thomas Hirst is also uneven, reporting on their falling out but ignoring their reconciliation. She also ascribes one quotation to both Sylvester and Peirce (pp. 329, 338). Crilly describes W.F. Donkin as the Oxford Savilian professor of mathematics, instead of astronomy, and presents William Spottiswoode as a founding member of the X-club, whereas he joined shortly after it was formed. Fortunately, however, in both books such errors and omissions seem to be rare and relatively unimportant.

The publishers are to be congratulated for bringing out these two biographies, and it is to be hoped that they will publish further biographies of Victorian mathematicians. They have produced two fine and well-printed volumes, although trying to concentrate on 10-point type can become somewhat wearisome after a few hundred pages.

It is tempting to speculate on what the outcome would have been had the authors followed the above-quoted wishes of Eric Temple Bell and produced a combined biography. Although much repetition would certainly have been avoided if the two books had been “shuffled together” like a deck of cards, and the similarities and differences between the two mathematicians might have emerged even more vividly, it is perhaps best that Crilly and Parshall chose to go their separate ways, for they have produced two independent yet complementary works of the highest scholarly standard. These magnificent achievements are unlikely to be supplanted for many years to come.

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