Three Savilian Professors of Geometry dominated Oxford's mathematical scene during the Victorian era: **Baden Powell** (1796–1860), **Henry John Stephen Smith** (1826–83) and **James Joseph Sylvester** (1814–97). None was primarily a geometer, but each brought a different contribution to the role.

Oxford's Victorian Savilian Professors of Geometry

The University Museum, constructed in the late 1850s, realised in brick and iron Oxford's mid-century aspirations to improve the facilities for teaching mathematics and the sciences.
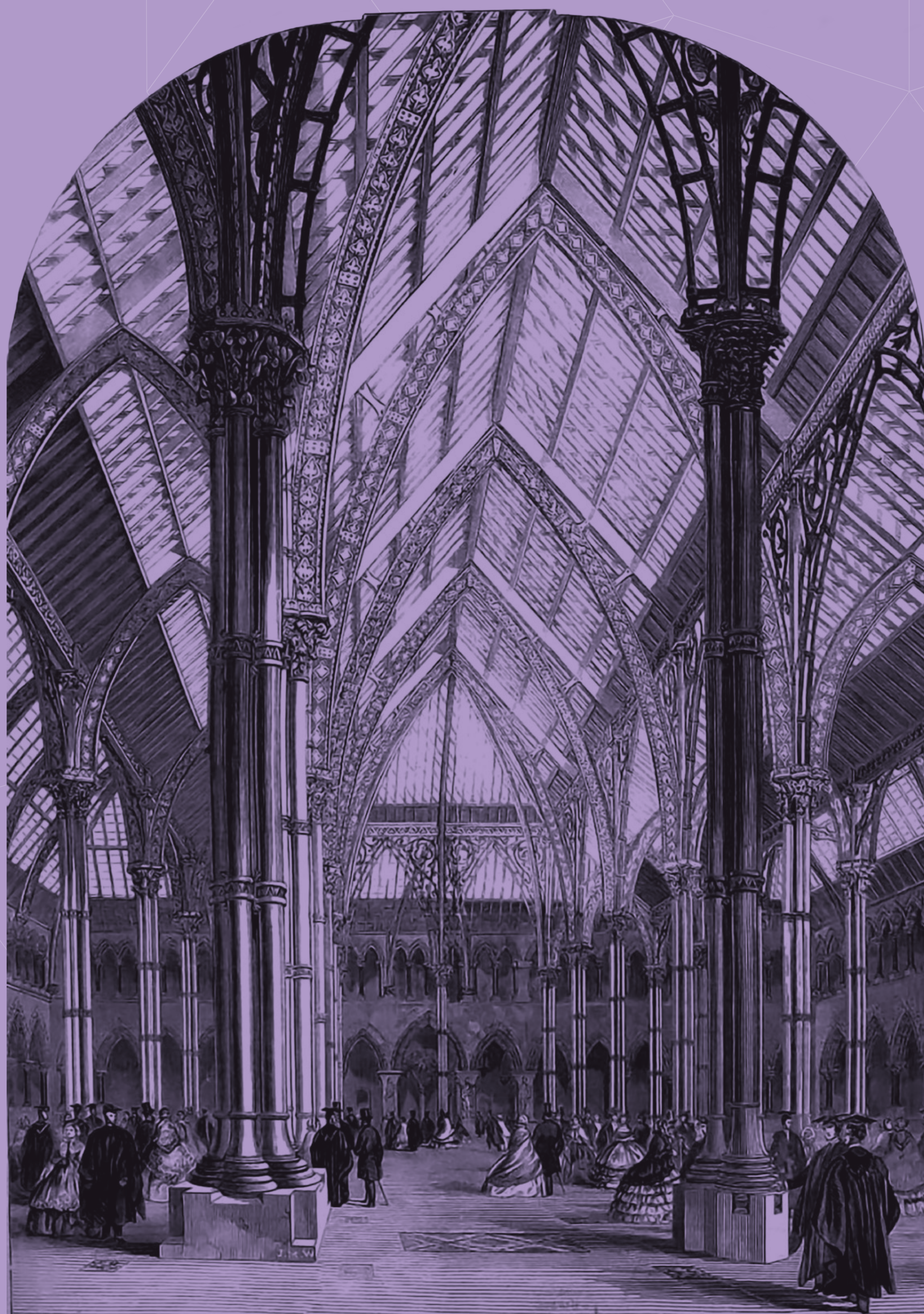
Time-line

|	
1827	Baden Powell elected Savilian Professor
1828	Mathematics Finals papers first published
1831	Mathematical Scholarships founded
1832	Powell's lecture on *The Present State and Future Prospects of Mathematics*
1847	BAAS meeting in Oxford
1849	School of Natural Science approved
1850–52	Royal Commission on Oxford University
1853	First college science laboratory
1859–65	Smith's *Reports on the Theory of Numbers*
1860	Opening of the University Museum
	Death of Baden Powell
	Henry Smith elected Savilian Professor
1861	The 'Smith normal form' of a matrix
1867	Smith's sums of squares
1868	Smith awarded Berlin Academy prize
1871	Non-Anglicans eligible to be members of Oxford University
1874	Smith appointed Keeper of the University Museum
1874–76	Henry Smith becomes President of the London Mathematical Society
1875	Smith's 'Cantor set'
1876	Ferdinand Lindemann visits Oxford
	Smith's lecture *On the Present State and Prospects of some Branches of Pure Mathematics*
1881	French Academy announces Grand Prix competition
1883	Death of Henry Smith
	J J Sylvester elected Savilian Professor
1885	Sylvester's inaugural lecture
1888	Oxford Mathematical Society founded
1894	William Esson elected Sylvester's deputy
1895–97	Smith's *Collected Papers* published
1897	Death of J J Sylvester
	William Esson elected Savilian Professor

Oxford
Mathematics

Oxford's Victorian Savilian Professors of Geometry
Baden Powell

Baden Powell was Savilian Professor of Geometry from 1827 to 1860.
One of his sons was later to found the Boy Scout movement.

Early Oxford career
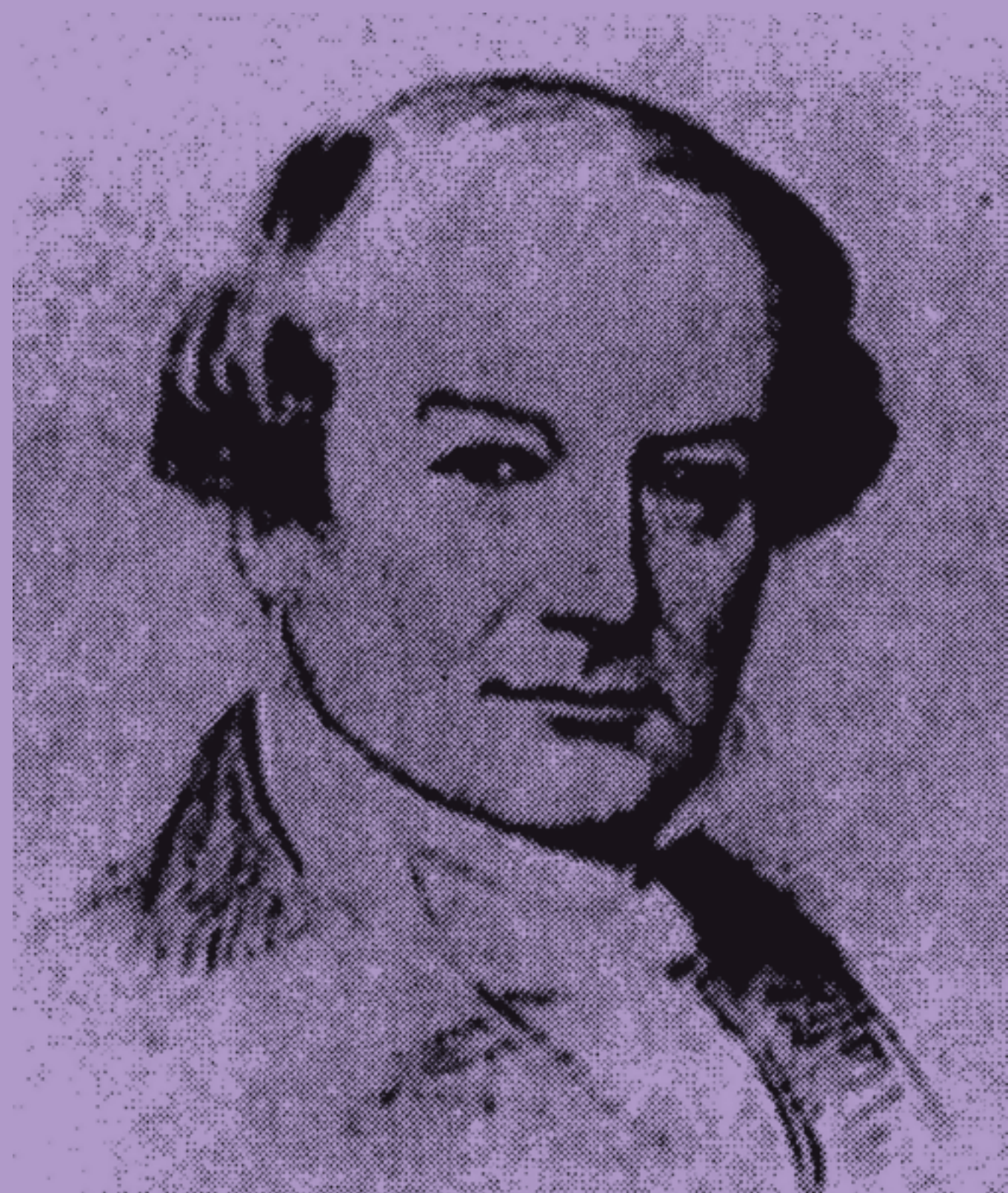
A drawing of the Revd. Baden Powell

A photograph of Powell taken by Nevil Story Maskelyne in the 1850s

Baden Powell graduated from Oriel College in 1817 with First Class Honours in Classics and Mathematics. He was primarily a physicist, with a special interest in optics, and was one of the first British scientists to embrace the wave theory of light.

In 1827 Stephen Rigaud, an astronomer and historian of mathematics, migrated from the Savilian Chair of Geometry to that of Astronomy, and Powell was elected as his successor. He began his tenure with high hopes for the part that he could play in raising the standard of mathematical education in Oxford.

The new Savilian professor was shocked and dismayed by the low esteem accorded to mathematics in the University. He was advised not to give an inaugural lecture as he would almost surely not attract an audience.

In 1832 he gave a public lecture on *The Present State and Future Prospects of Mathematical and Physical Sciences in the University of Oxford*, in which he bemoaned the declining number of science students.

Ever since the Honours School in Mathematics had been introduced in 1800 students had become more exam-focused and less interested in the subject as a whole. Powell complained that, for examinations, 'though a certain portion had "got up" the four books of Euclid, not more than two or three could add Vulgar Fractions or tell the cause of day or the principle of a pump'. An examiner of the time told of a student who reproduced a proof of Euclid perfectly, but in his diagrams drew all the triangles as circles.

With great energy Powell set about changing things, but he lacked the political ability to carry through more than a few modest changes. His most successful innovation, however, was to create scholarships for the promotion of mathematical studies. These were founded in 1831, and were subsequently awarded to a number of notable mathematicians, such as William Spottiswoode (later President of the Royal Society) and Bartholomew Price (Sedleian Professor of Natural Philosophy).

Baden Powell was the first prominent churchman to embrace Charles Darwin's views on *The Origin of Species*, in a contribution to *Essays and Reviews*, published just before his death in 1860.

Powell, the populariser
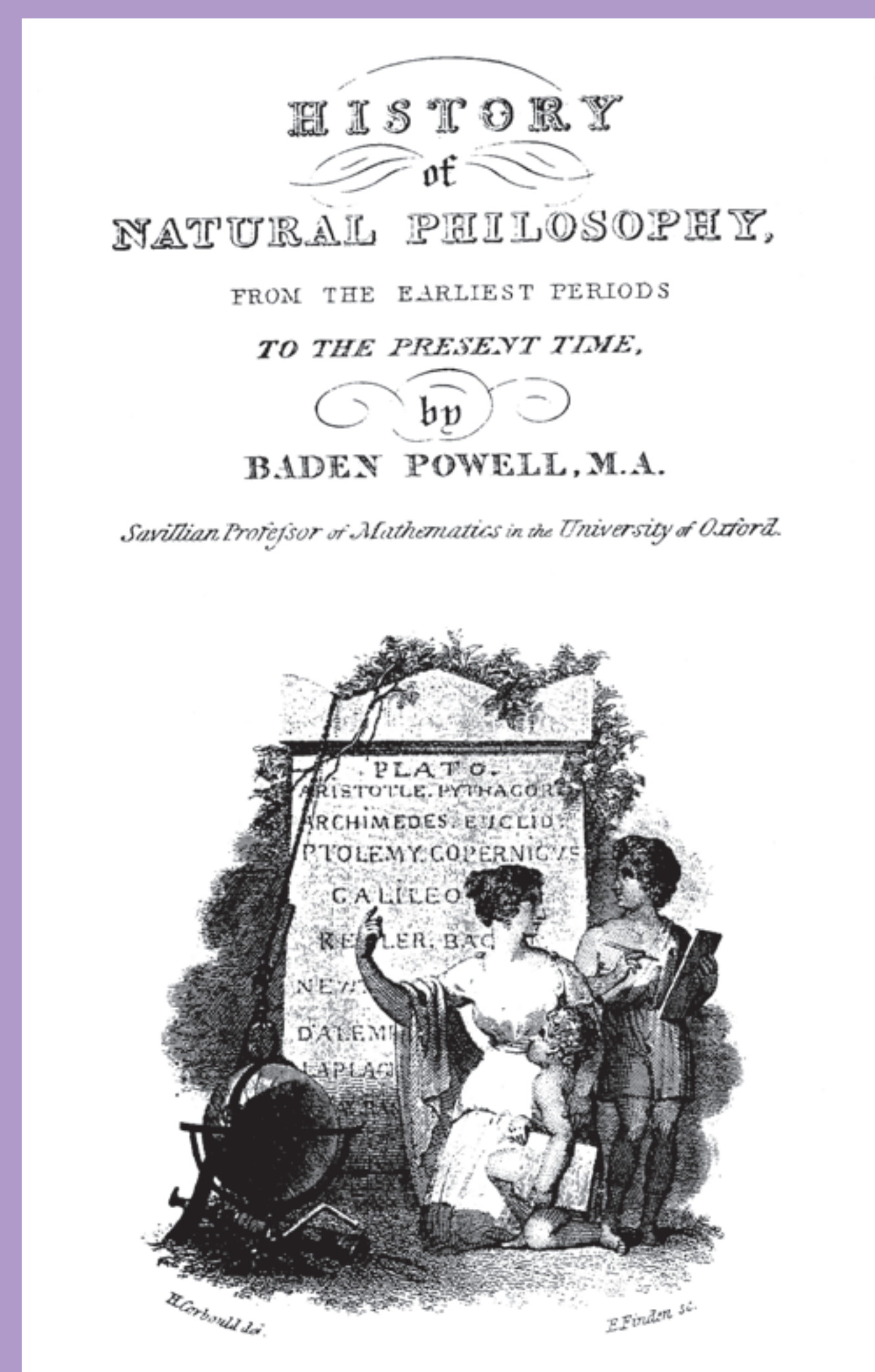
In order to promote scientific awareness among the general public, Baden Powell wrote this history of the physical and mathematical sciences

Powell was an accomplished public speaker and he set out on a crusade to educate people through his popular lectures and writings. When the British Association for the Advancement of Science was founded in 1831, he became an enthusiastic supporter.

The Association held its second meeting in Oxford in 1832 and returned in 1847, 1860 and 1894.

At the 1847 meeting Baden Powell gave a two-hour popular lecture on 'Falling stars' to a large audience. The highlight of the mathematical section's proceedings was a lecture by John Couch Adams on the recent discovery of Neptune, in the presence of its French independent co-discoverer Urbain Le Verrier. Indeed, it was in Powell's house at this meeting that Adams and Le Verrier met for the first time.
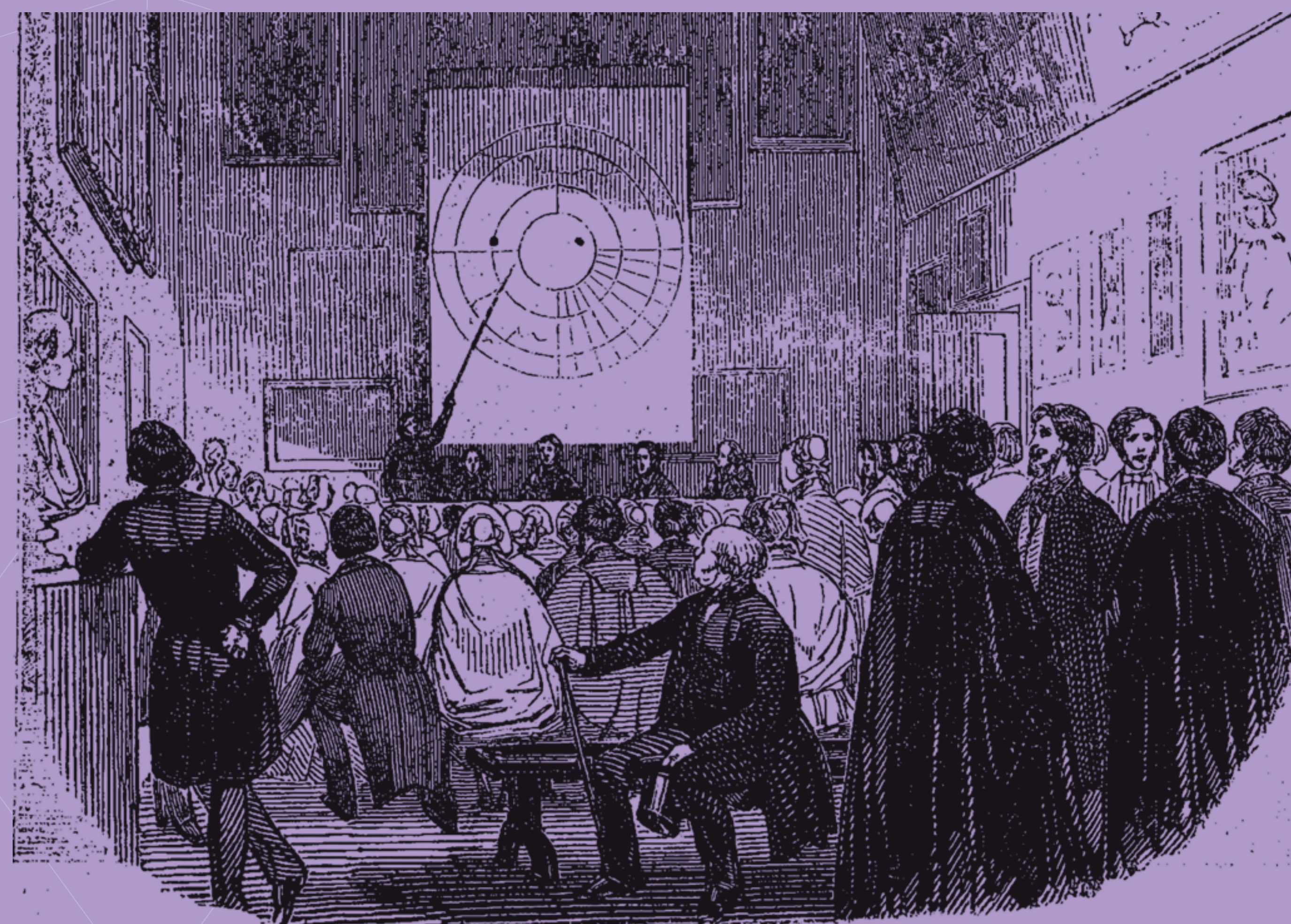
The British Association meeting of 1847

Oxford's Victorian Savilian Professors of Geometry
Henry Smith in Oxford

Baden Powell had put Oxford mathematics back on the map,
but it was Henry Smith who brought it international recognition.

Early Oxford career

Henry Smith gained First Class Honours in both Classics and Mathematics in 1849 after only seven terms in Oxford, and won the Senior Mathematical Scholarship. He was elected to the Mathematical Lectureship at Balliol College later in that year.

Besides teaching at Balliol he was also asked to run the College's laboratory for the newly introduced Natural Science course. For this purpose he was sent to study chemistry with Nevil Story Maskelyne in the Old Ashmolean Museum.
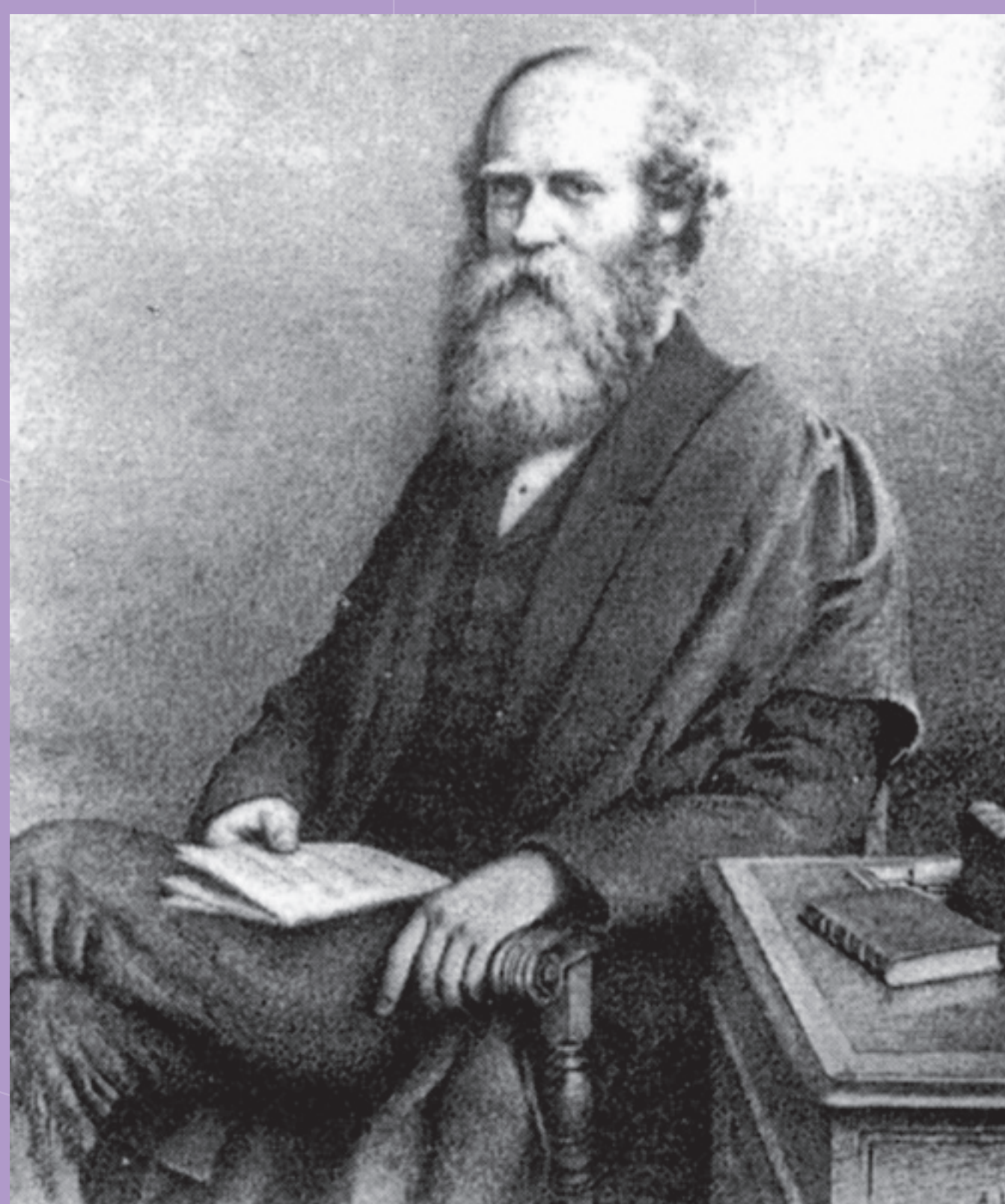

A caricature of Smith by a student

The widespread affection for Henry Smith across the University Community can be gleaned from the above caricature of him. As a former student wrote after Smith's death:
'Alas!… that his flowing beard and flying gown will be seen no more, for his place cannot be filled.'

A photograph of Henry Smith, taken around 1850 by his friend and collaborator Nevil Story Maskelyne

Following Baden Powell's sudden death in 1860, Smith was elected Savilian Professor of Geometry. Apparently the other, somewhat reluctant, candidate was George Boole (of Boolean algebra fame), but Smith soon justified the electors' faith in him, in a series of important research papers that applied the new concept of matrices to number theory.

Henry Smith in old age

Smith and Oxford University

The University Museum in 1860

The early 1870s brought a number of changes in Smith's life. In 1874 he was appointed Keeper of the University Museum, and lived in the Keeper's house at the right of this 1861 print. His sister, Eleanor, kept house for him. An impressive scholar in her own right, she started the 'Women's lectures' in Oxford during the 1860s.

Smith was also elected to a professorial fellowship at Corpus Christi College, which enabled him to give up the tutorial teaching he had continued to do at Balliol, though he continued as an Honorary Fellow there. These changes gave him more time to spend on his research.

In addition to his mathematical work he played a key role in the various reforms that transformed Oxford into a modern university.

The University was undergoing some major changes, and Smith served on the Royal Commission which set the framework for this. He was also on the Royal Commission on Scientific Education.

Smith could persuade where the other Oxford reformers antagonised: 'He could say the happy word which quelled a rising storm'.
His background in classics, mathematics and chemistry gave him an exceptionally broad perspective.

Oxford's Victorian Savilian Professors of Geometry
Henry Smith's mathematics

Henry Smith had an international reputation, and he was the only 19th-century British mathematician to win major scientific prizes from both France and Germany.

Smith's mathematical research

> Report on the Theory of Numbers.—Part I.
> By H. J. Stephen Smith, M.A., Fellow of Balliol College, Oxford.
>
> 1. The 'Disquisitiones Arithmeticæ' of Karl Friedrich Gauss (Lipsiæ, 1801) and the 'Théorie des Nombres' of Adrien Marie Legendre (Paris, 1830, ed. 3) are still the classical works on the Theory of Numbers. Nevertheless, the actual state of this part of mathematical analysis is but

Henry Smith's *Report on the Theory of Numbers*

In addition to his diverse teaching responsibilities, Henry Smith began a systematic study of Number Theory, an area rather neglected by British mathematicians. The British Association for the Advancement of Science commissioned him to prepare a *Report on the Theory of Numbers*, a comprehensive survey of the subject, which appeared in six instalments between 1859 and 1865.

SUMS OF SQUARES

In 1861 Smith showed that any matrix with integer entries can be reduced by row and column operations to a diagonal form in which each diagonal entry divides its successors. This enabled him to give a complete solution of a problem studied in antiquity, giving precise conditions for when simultaneous equations with integer coefficients have integer solutions.

In 1867 a subtle application of these same ideas enabled Smith to solve another problem in number theory. In 1621 it was conjectured that every positive integer can be written as the sum of four squares (sometimes in several ways), a result proved by Lagrange in 1770.

For example:
$4 = 2^2 + 0^2 + 0^2 + 0^2$ or $1^2 + 1^2 + 1^2 + 1^2$
and $7 = 2^2 + 1^2 + 1^2 + 1^2$

Similar questions may be asked for sums of five, six, or seven squares, and Smith used his earlier matrix theorem to obtain solutions for all cases by a uniform method.

In the course of this work he also showed that in eight dimensions, there is an exceptional lattice of points different from the standard lattice of points with integer coordinates. This lattice, now known as E8, plays an important role in the study of symmetry and physics and was recently shown to give the optimal sphere packing in eight dimensions.

In 1875 he published a paper on the theory of integration, in which his examples showed how to integrate some rather badly behaved functions. One of these examples was probably the first published example of a fractal. It considered functions that were discontinuous at the points of what is now called a 'Cantor set', though Cantor published a special case of it only some years later.

Smith was President of the London Mathematical Society from 1874 to 1876. His wide-ranging Presidential address *On the Present State and Prospects of some Branches of Pure Mathematics* surveyed, among other things, work on prime numbers by Riemann and Chebyshev, as well as Hermite's recent proof of the transcendence of *e*.

International prizes

Smith regularly invited Continental mathematicians, such as Charles Hermite and Felix Klein, to talk at the British Association meetings.

In June 1876 his guest in Oxford was the young Ferdinand Lindemann, with whom he discussed the possibility of showing that π is transcendental – that is, it is not a root of any polynomial equation with integer coefficients. Five years later this was proved by Lindemann, finally settling various questions which had been raised in antiquity.
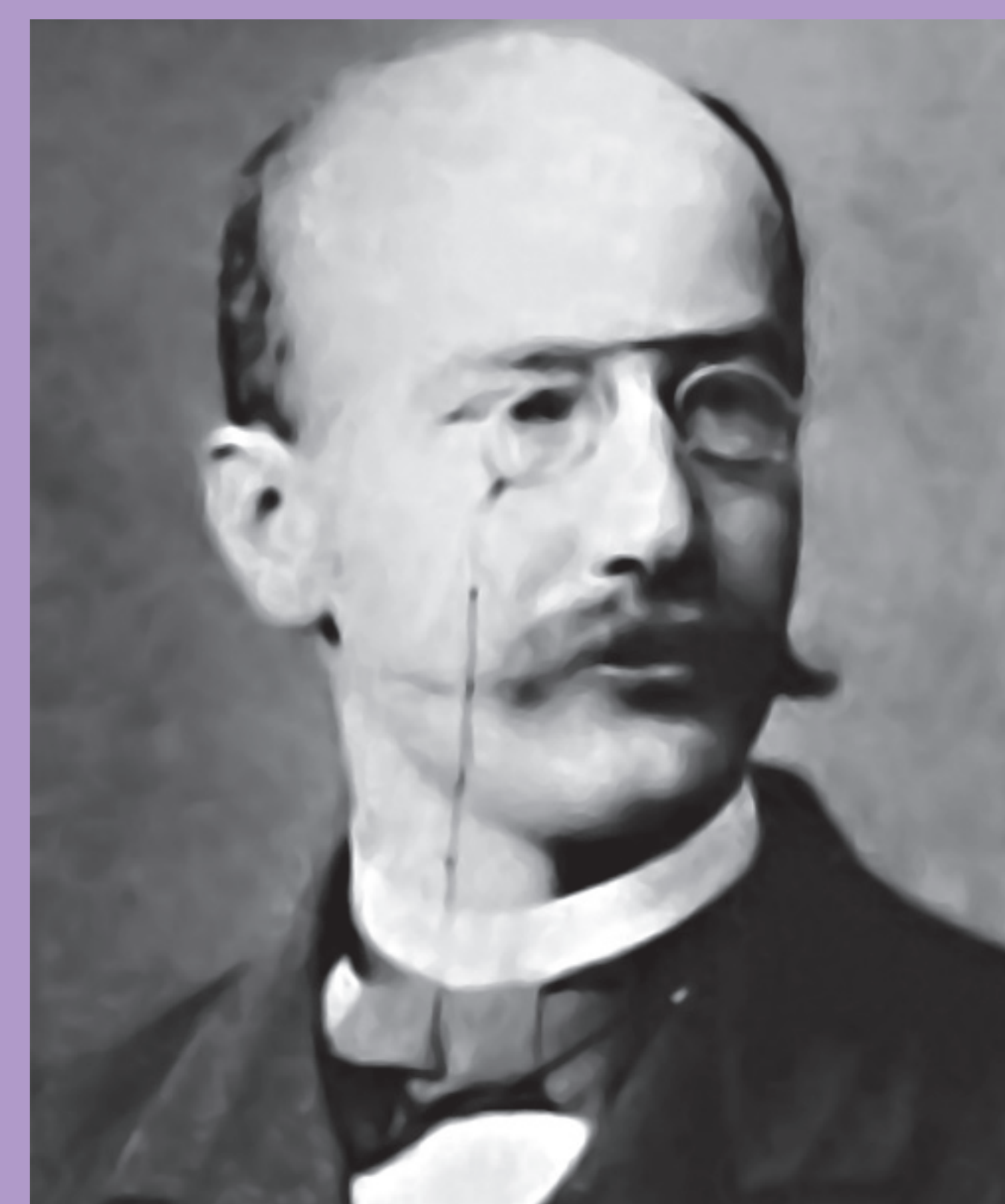
Ferdinand Lindemann

In 1869 the Berlin Academy of Sciences awarded Smith its Steiner prize for producing a geometric construction (with algebraic justification) for the other three points of intersection of two quartic curves when 13 of the 16 points are already known.

In 1881, whilst recuperating from a fall, he noticed that the French Academy of Sciences was offering its Grand Prix for solving the very problem of representing positive integers as sums of squares that he had published in 1867. He wrote to Hermite to point this out and received an embarrassed reply, suggesting that he submit his earlier result (in French) for the prize. Smith complied, but he died in February 1883 before the prize was awarded.

Charles Hermite

Two months later it was announced that the prize would be shared by Smith and a young Prussian student Hermann Minkowski. Journalists soon discovered that Smith's solution had been published many years before, and accused Minkowski of plagiarism. Whether Minkowski knew of Smith's paper is unclear, but he went on to become one of the leading researchers in number theory, an admirer of Smith's work, and his worthy scientific successor.

Hermann Minkowski

Oxford's Victorian Savilian Professors of Geometry

James Joseph Sylvester

J J Sylvester was Savilian Professor of Geometry from 1883 to 1897. He was appointed at the age of 69.

Sylvester comes to Oxford

James Joseph Sylvester

Henry Smith's untimely death in 1883 created another vacancy for the Savilian Chair of Geometry. Sylvester had spent seven years as the first Mathematics Professor at the newly founded Johns Hopkins University in Baltimore, USA. Wishing to return to his home country he decided to apply.

As a Jew who had not been allowed to receive his degree from Cambridge in the 1830s, he feared that his religion might still count against him. Also, he was already 69 and was a non-Oxford man. As he wrote to his friend, the Cambridge mathematician Arthur Cayley:
'Do you think I am likely to be appointed? If the chances are considerably against me – it would be impolitic to offer – but perhaps even if impolitic it would be right on my part to do so by way of testing what I consider – although you may not perhaps agree with me – an important principle.'
Indeed, attempts had been made to persuade him to withdraw on account of his age. But, as the greatest British mathematician of his time, he was chosen unanimously by the seven electors.

His inaugural lecture took place in December 1885, two years after his election, and had the snappy title of *On the method of reciprocants as containing an exhaustive theory of the singularities of curves*. This lecture, in which he paid warm respects to his Savilian predecessors Henry Briggs, John Wallis, Edmond Halley and Henry Smith, was vintage Sylvester – even down to the recital of a sonnet of his own composition, under the inspiration of discovering that a term involving b^4d did not appear where it might be expected to, in a table of reciprocative protomorphs. It begins:

TO A MISSING MEMBER
Of a Family Group of Terms in an Algebraical Formula
Lone and discarded one!
  divorced by fate,
From thy wished-for fellows –
  whither art flown?
Where lingerest thou in thy
  bereaved estate,
Like some lost star, or buried
  meteor stone?…
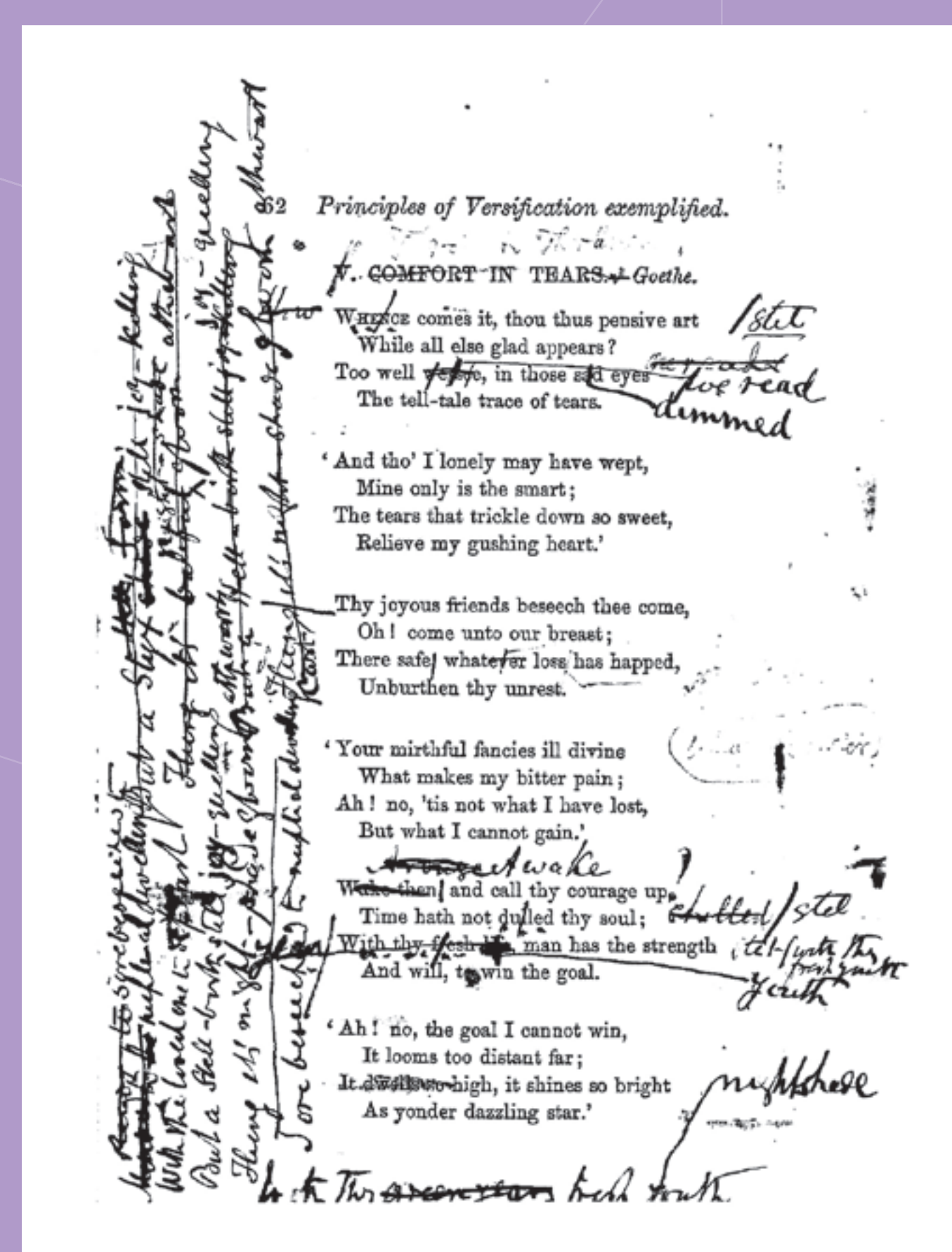
In his *Laws of Verse* Sylvester set out his view of the mathematical laws that govern the writing of poetry. His extensive annotations appear in his copy, now in the Mathematical Institute

Sylvester's teaching

Whereas Henry Smith had been a painstaking college tutor, Sylvester could only lecture on his own researches, which was not popular in a place so wholly given over to examinations. His high-minded teaching strategy, as outlined in his inaugural lecture, was as follows:
'I think that I shall best discharge my duty to the University by selecting for the material of my work in the class-room any subject on which my thoughts may, for the time being, happen to be concentrated, not too alien to, or remote from, that which I am appointed to teach; and thus, by example, give lessons in the difficult art of mathematical thinking and reasoning – how to follow out familiar suggestions of analogy till they broaden and deepen into a fertilising stream of thought – how to discover errors and repair them, guided by faith in the existence and unity of that intellectual world which exists within us, and is at least as real as that with which we are environed.'

As a result, Sylvester's lectures were too remote from the examination needs of students, and few students attended them:
'Here in Oxford I am fortunate if I get an auditory of 6 persons… I begin to feel therefore very like the stalled Ox.'

However, some aspects of his teaching were notable. He arranged a grant from the University to purchase from Germany a set of geometrical models for a course of lectures 'On surfaces, illustrated by plaster, string, and card-board models'. He announced his lectures for Tuesdays and Saturdays, commencing on Saturday October 23, 1886 at 4.30pm.
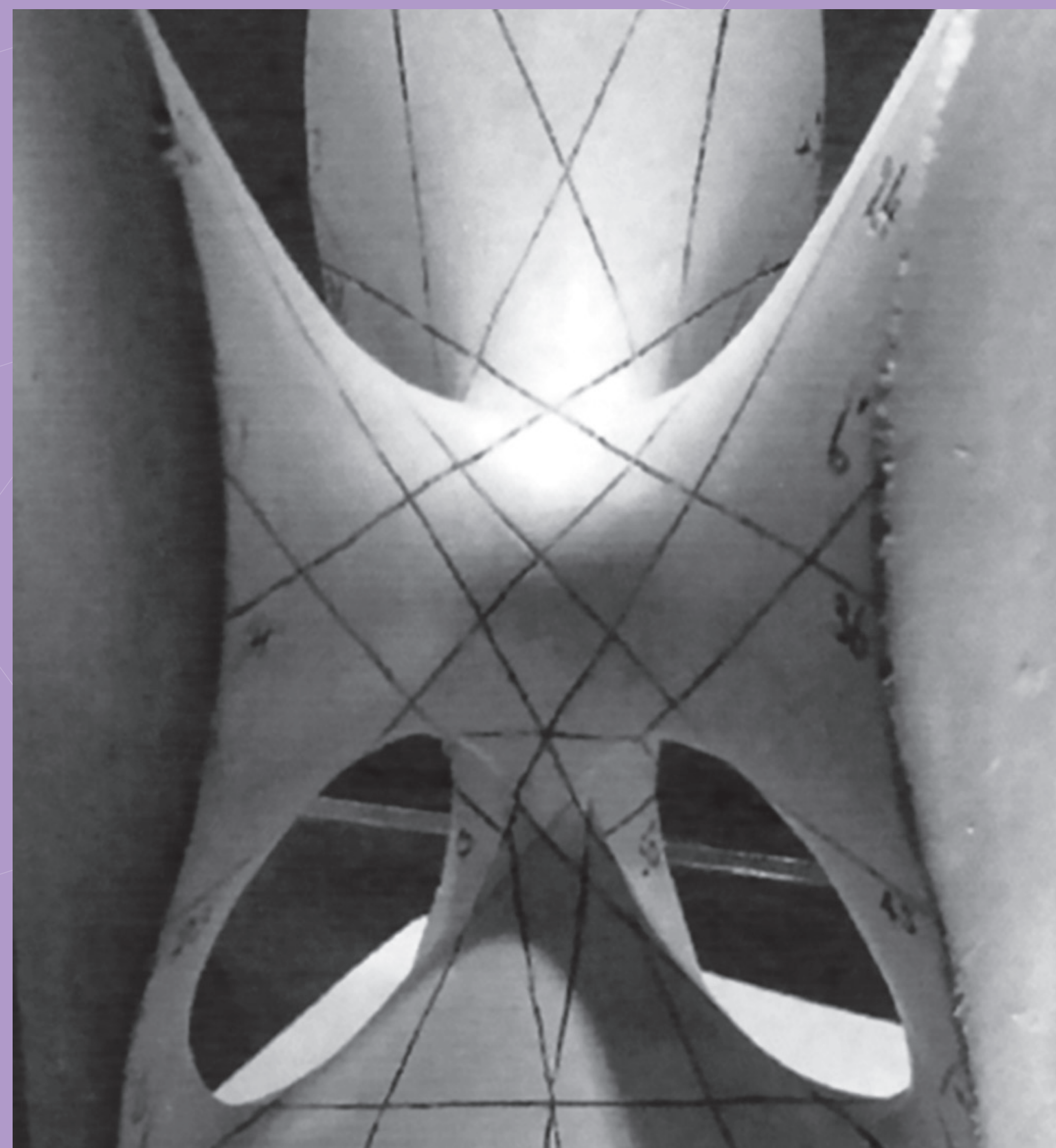
This plaster model, purchased by the University in 1886, illustrates the 27 lines on a cubic surface. As well as his course, Sylvester gave a public lecture on these models

Sylvester as Savilian Professor

As a way of encouraging more research activity, Sylvester founded the Oxford Mathematical Society. But his age was beginning to take its toll…

Oxford research

Coming from Baltimore, where he had built up a mathematics research community, Sylvester was surprised and disappointed to find no such community in Oxford: all that seemed to matter was examinations. In a letter to Daniel Gilman, President of Johns Hopkins University, he wrote: 'Entre nous this university except as a school of taste and elegant light literature is a magnificent sham. It seems to me that Mathematical science here is doomed and must eventually fall off like a withered branch from a tree which derives no nutriment from its roots.'

In order to encourage his colleagues to take an interest in creative mathematics, he founded the Oxford Mathematical Society. As Arthur Cayley remarked: 'Wherever Dr Sylvester goes, there is sure to be mathematical activity; and the latest proof of this is the formation, during the last term at Oxford, of a Mathematical Society, which promises, we hear without surprise, to do much for the advancement of mathematical science there.'

At its first meeting on 9 June 1888, Sylvester was elected President. There were two Vice-Presidents – William Esson, later to be Sylvester's successor in the Savilian Chair, and Bartholomew Price, the Sedleian Professor of Natural Philosophy. The secretary was E B Elliott, soon to be the first Waynflete Professor of Pure Mathematics. The Society met six times per year, with about three or four papers read at each meeting, and for many years was the only forum in Oxford for discussion of research-level mathematics. The list of original members is shown below.

THE OXFORD MATHEMATICAL SOCIETY.

NOVEMBER, 1888.

List of Original members.

President.
J. J. SYLVESTER, M.A., F.R.S., Savilian Professor of Geometry.

Vice-Presidents.
REV. BARTHOLOMEW PRICE, M.A., F.R.S., Sedleian Professor of Natural Philosophy.
WILLIAM ESSON, M.A., F.R.S., Merton College.

Secretary.
E. B. ELLIOTT, M.A., Queen's College.

R. E. BAYNES, M.A., Ch. Ch.
REV. J. BELLAMY, D.D., Vice-Chancellor, and President of St. John's.
C. E. BICKMORE, M.A. New College.
T. BOWMAN, M.A., Merton College.
J. E. CAMPBELL, B.A., Hertford College.
A. W. CAVE, M.A., Magdalen College.
REV. R. H. CHARSLEY, M.A., St. Mary Hall.
REV. J. CHEVALLIER, M.A., New College.
R. B. CLIFTON, M.A., F.R.S., Professor of Experimental Philosophy.
REV. H. DEANE, B.D., St. John's College.
J. M. DYER, M.A., Worcester College.
C. J. FAULKNER, M.A., University College.
H. T. GERRANS, M.A., Worcester College.
J. GRIFFITHS, M.A., Jesus College.
J. HAMMOND, M.A., Queen's College, Camb.
C. E. HASELFOOT, B.A., Hertford College.

REV. R. HARLEY, M.A., F.R.S.
E. H. HAYES, M.A., New College.
C. LEUDESDORF, M.A., Pembroke College.
A. LODGE, M.A., St. John's College.
D. B. MONRO, M.A., Provost of Oriel College.
C. J. C. PRICE, M.A., Exeter College.
REV. C. PRITCHARD, M.A., F.R.S., Savilian Professor of Astronomy.
L. J. ROGERS, M.A., Balliol College.
J. W. RUSSELL, M.A., Merton College.
C. H. SAMPSON, M.A., B.N.C.
REV. E. F. SAMPSON, M.A., Ch. Ch.
A. L. SELBY, M.A., Merton College.
REV. F. J. SMITH, M.A., Trinity College.
E. J. STONE, M.A., F.R.S., Ch. Ch., Radcliffe Observer.
REV. G. S. WARD, M.A., Hertford College.
J. COOK WILSON, M.A., Oriel College.

Women's education and his retirement

SYLVESTER AND WOMEN'S EDUCATION

Sylvester was always a great supporter of women's education, helping mathematicians such as the American Christine Ladd. Among women mathematicians that he particularly admired was the Russian Sonya Kowalevskaya, whom he referred to in one of his sonnets.

Above: Sonya Kowalevskaya
Below: Mary Somerville

The most famous woman of 19th-century British science, and a keen advocate of women's mathematics education, was Mary Somerville, after whom the Oxford college was named.

It was not until 1920 that women were admitted to Oxford degrees and full University membership.

Like his predecessor, Henry Smith, Sylvester kept in regular touch with international colleagues. He wrote to David Hilbert and Felix Klein, and invited to Oxford the Danish mathematician Julius Petersen, with whom he worked on some graph theory.

But he realised that his mathematical interests were becoming increasingly out of date. As he wrote to Arthur Cayley: 'I expect Poincarre [the French mathematician Henri Poincaré] tomorrow and he will have rooms in College. I rather dread the encounter as there is so little in the way of Mathematics upon which I can hope to talk to him.'

Meanwhile his body was gradually weakening, and eventually his eyesight deteriorated to such an extent that a deputy had to be appointed to carry out his lecturing tasks. This was William Esson, an established Oxford figure who succeeded him after his death in 1897. But it would not be until after the First World War that a true research ethos came into being in Oxford mathematics, with the arrival of G H Hardy.

William Esson

Oxford Mathematics