

INTRODUCTION

Historical accounts of successful laboratories often consist primarily of reminiscences by their directors and the eminent people who studied or worked in these laboratories. Such recollections customarily are delivered at the celebration of a milestone in the history of the laboratory, such as the institution's fiftieth or one-hundredth anniversary. Three such accounts of the Cavendish Laboratory at the University of Cambridge have been recorded. The first of these, *A History of the Cavendish Laboratory, 1871-1910*, was published in 1910 in honor of the twenty-fifth anniversary of Joseph John Thomson's professorship there. The second, *The Cavendish Laboratory, 1874-1974*, was published in 1974 to commemorate the one-hundredth anniversary of the Cavendish. The third, *A Hundred Years and More of Cambridge Physics*, is a short pamphlet, also published at the centennial of the Cavendish.¹ These accounts are filled with the names of great physicists (such as James Clerk Maxwell, Lord Rayleigh, J.J. Thomson, Ernest Rutherford, and William Lawrence Bragg), their glorious achievements (for example, the discoveries of the electron, the neutron, and DNA) and interesting anecdotes about how these achievements were reached. But surely a narrative that does justice to the history of a laboratory must recount more than past events. Such a narrative should describe a living entity and provide not only details of the laboratory's personnel, organization, tools, and tool kits, but should also explain how these components interacted within their wider historical, cultural, and social contexts.²

¹ J.J. Thomson et al., *A History of the Cavendish Laboratory, 1871-1910* (London: Longmans, Green, 1910); J. G. Crowther, *The Cavendish Laboratory, 1874-1974* (New York: Science History Publications, 1974); Cambridge University Physics Society, *A Hundred Years and More of Cambridge Physics* (Cambridge, 1974, 1980, 1995). Other histories are: A. Wood, *The Cavendish Laboratory* (Cambridge: Cambridge University Press, 1946); E. Larson, *The Cavendish Laboratory: Nursery of Genius* (London: Ward, 1962); G. P. Thomson, *J.J. Thomson and the Cavendish Laboratory* (London: Thomas Nelson & Sons, 1964).

² Some notable examples of recent studies of the histories of various laboratories (and research schools) are: J. B. Morrell, "The Chemist Breeders: The Research Schools of Liebig and Thomson," *Ambix* 19 (1972): 1-46; Gerald Geison, *Michael Foster and the Cambridge School of Physiology: The Scientific Enterprise in Late Victorian Society* (Princeton: Princeton University Press, 1978); Bruno Latour and Steve Woolgar, *Laboratory Life: The Social Construction of Scientific Facts* (Beverly Hills, Calif.: Sage, 1979); Frederic L. Holmes, *Lavoisier and the Chemistry of Life: An Exploration of Scientific Creativity* (Madison: University of Wisconsin Press, 1984); John L. Heilbron and Robert W. Seidel, *Lawrence and His Laboratory: A History of the Lawrence Berkeley Laboratory*, vol. 1 (Berkeley: University of California Press, 1989); Joseph S. Fruton, *Contrasts in Scientific Style: Research Groups in the Chemical and Biochemical Sciences* (Philadelphia: American Philosophical Society, 1990); Kathryn M. Olesko, *Physics as a Calling: Discipline and Practice in the Königsberg Seminar for Physics* (Ithaca, New York: Cornell University Press, 1991); and Robert E. Kohler, *Lords of the Fly: Drosophila Genetics and the Experimental Life* (Chicago: University of Chicago Press, 1994). Valuable discussions about research schools are found in Gerald L. Geison and Frederic L. Holmes (ed.), *Research Schools: Historical Reappraisals*, *Osiris* 8 (1993).

My goal in writing this book was to deliver a critical history of the Cavendish Laboratory in its early years. At the core of this book is my belief that the evolution of the Cavendish Laboratory was not as smooth as the reader of previous historical accounts might expect. Contrary to the suggestions of earlier accounts, the prestige of the Cavendish's first directors, Maxwell, Lord Rayleigh, J.J. Thomson, and even Rutherford, did not automatically guarantee the Laboratory smooth sailing and a rosy future. Similarly, the 1895 change in University policy that permitted non-Cambridge graduates to study at the Cavendish did not promise the Laboratory's sudden elevation to the status of important research center. Instead, the Cavendish evolved from a relatively small university teaching laboratory to the world center of experimental physics through a *slow but steady* accumulation of knowledge and human resources. To present the history of the Cavendish Laboratory from this perspective, I have described and analyzed the participants in the Laboratory's development, as much as possible, in terms of their contributions to that development.

This book answers the following questions. What made it possible to create the Cavendish Laboratory in the 1870s? What was the Laboratory's principal role within Cambridge University and how did this role change over time? Who performed research at the Cavendish, when did they work there, and what topics did they investigate? In what ways and to what extent did the Laboratory's directors influence the work of Cavendish researchers? How did the Cavendish become the mecca of experimental physics during the first third of the twentieth century? In short, why was the Cavendish Laboratory so successful?

Throughout this book, special attention has been given to Cambridge University's influence on the Cavendish Laboratory. Not only did the Cavendish develop within this venerable University, but it also advanced in tandem with the University's educational system. Despite this close relationship, a struggle between the University's old traditions and the Laboratory's new values could not be avoided because the Cavendish propagated new modes of doing science. The early history of the Cavendish, therefore, illustrates the manner in which conflicts between traditional and new values were negotiated in late Victorian Cambridge. In concentrating on the Cavendish's context within Cambridge University, however, I have somewhat minimized the Laboratory's relationship with the outside world.

From 1860 to 1930, higher education in Europe was undergoing transformation from systems that were "small, homogeneous, elite and pre-professional" to systems that were "large, diversified, middle-class and professional."³ The engine of this change was the second industrial revolution, during which science and technology became revered as the keys to society's goals. As Germany and the United States transformed their educational systems to meet the challenge of industrialization,

³ Konrad H. Jarausch, "Higher Education and Social Change: Some Comparative Perspectives," in Konrad H. Jarausch (ed.), *The Transformation of Higher Learning 1860-1930: Expansion, Diversification, Social Opening, and Professionalization in England, Germany, Russia, and the United States* (Chicago: University of Chicago Press, 1983), 10.

efforts in Britain to adapt education to the new technological challenges were largely unsuccessful until the Paris International Exhibition of 1867, which made it obvious that industrial development was flourishing on the Continent and in the United States much more than on the British Isles. This realization intensified the efforts of British educational reformers to advance their pro-scientific program, even in the tradition-steeped halls of Oxford and Cambridge. However, the most important educational changes in England did not occur in existing universities (as they did in Germany and the United States), but in newly established regional colleges and universities.⁴ Oxford and Cambridge remained as aloof as possible to public pressure for change, and whatever small concessions the two universities made to educational reformers were made at a foot-dragging pace.

Cambridge University, in a "least possible" response to pressure for greater educational emphasis on science and technology, in the 1870s established a professorship of experimental physics and a professorship of engineering, at the same time instituting the Cavendish Laboratory and Michael Foster's physiological laboratory. The Cavendish was quickly absorbed into the University's existing system, and the Laboratory's development was hampered by that system's painfully slow evolution. As late as 1873, the Royal Commission on Scientific Instruction and the Advancement of Science (better known as the Devonshire Commission) considered it necessary to remind Oxford and Cambridge about the importance to the universities of research in the sciences. To persuade Oxford and Cambridge to establish more teaching positions in the sciences, the Commission included in its report comparisons of the University of Berlin and the two British universities that showed the Oxbridge system to be wanting.⁵ Nevertheless, Oxford and Cambridge delayed for a full decade before reluctantly establishing a few new lectureships in the sciences in 1883.

Thus, to understand the Cavendish Laboratory, one first must understand Cambridge University and the radical changes it experienced during the nineteenth century. In 1800, the University was a bastion of traditions (some of which could be traced back to the Middle Ages) and a closed, male-only community which allowed only its own graduates to pursue advanced study within its halls or to serve as fellows or officers. Its primary goal was to produce educated gentlemen, sound in mind and body, according to the tenets of the Church of England, to which the University had been tightly bound by the Religious Test Act since the seventeenth century. Along with mathematics, the classics, and philosophy, a Cambridge education emphasized rowing, fencing, swimming, and social gathering.⁶ Professors

⁴ Graeme Gooday, "Precision Measurement and the Genesis of Physics Teaching Laboratories in Victorian Britain," *BJHS* 23 (1990): 25-51 on 25-31.

⁵ Royal Commission on Scientific Instruction and the Advancement of Science, "The Report of the Science Commission of the Old Universities," *Nature* 8 (1873): 317-319, 337-341. See also Roy M. MacLeod, "Resources in Science in Victorian England: The Endowment of Science Movement, 1868-1900," in Peter Mathias (ed.), *Science and Society 1600-1900* (Cambridge: Cambridge University Press, 1972), 111-166.

⁶ For more about student life at Cambridge at the turn of the nineteenth century, see Sheldon Rothblatt,

were few, and most teaching was done by tutors affiliated with the various colleges in Cambridge. Research was regarded as a purely private activity. By 1900, however, students who had graduated from colleges and universities outside Cambridge were permitted to enter the University as “advanced students.” Women had entered the University, and its connections with the Church of England had been relaxed. The number of Cambridge professors, university lecturers, and university demonstrators had greatly increased, and they had become chiefly responsible for educating students. Research had taken firm root in Cambridge’s educational system, and a few of its research centers, including the Cavendish Laboratory, had become world famous. By 1900, Cambridge University was a leading institution for the study of the humanities, social sciences, medicine, and modern science.

Such rapid change had not been altogether welcome at Cambridge. Resistance, clashes, delays, and compromise were inevitable, and the result was a unique mixture of old and new that distinguished Cambridge from other universities. In 1908, Karl Breul, Cambridge’s Schröder Professor of German, accurately characterized the University’s intellectual atmosphere as:

a happy blending of tradition and freedom, of ancient customs and new methods; a careful adapting [of] old institutions to modern needs, of training the intellect and moulding the character . . . The old humanistic tradition of classical studies in Cambridge is, by the best of her sons, successfully applied to the more modern studies.⁷

The typical nineteenth-century Cambridge undergraduate pursued his bachelor’s degree for three academic years, each of which consisted of three terms: the Michaelmas term (October to December), the Lent term (January to March), and the Easter term (May to June). To “keep his term,” the undergraduate was required to reside in Cambridge for a specified number of days. Most students stayed an additional term to take the January Senate House examination (also known as the tripos examination) necessary to earn a Cambridge “bachelor’s” degree. Some stayed even longer to prepare for college fellowships. During the “Long Vacation” of summer, only the most diligent students remained in Cambridge to prepare for examinations, perform research, or study in a quiet atmosphere. Most undergraduates came to Cambridge from elite “public” schools like Eton or Harrow, but some scholarship students were graduates of small country grammar schools.

The University was a federation of colleges in which each member college enjoyed independent administration and traditions and, according to its size and wealth, contributed financially to the University. The position of Vice-Chancellor of the University was filled, in rotation, by a head (Master) of one of the colleges. Each college selected its own students, and what mattered most to the daily life

“The Student Sub-Culture and the Examination System in Early 19th Century Oxbridge,” in Lawrence Stone (ed.), *The University in Society, Volume 1: Oxford and Cambridge from the 14th to the Early 19th Century* (Princeton: Princeton University Press, 1974), 247-303.

⁷ Karl Breul, *Students’ Life and Work in the University of Cambridge: Two Lectures*, revised edition (Cambridge: Bowes and Bowes, 1910), 5.

of the typical Cambridge student was not affiliation with the University, but affiliation with a college: the place where one studied, dined, played, and slept, ultimately to become a “Trinity man,” a “King’s man,” or a “Newnham lady (or woman).” A small minority of Cambridge University students had no specific college affiliation; because they were “non-collegiate,” their social status was lower than that of other students. For most Cambridge students, the University became a palpable force in daily life only when they matriculated into the University, when they took University examinations, and when they received their Cambridge University degrees.

Cambridge colleges managed and educated their students through a unique system in which every undergraduate was required to have a tutor:

a graduate of experience and great influence in the college, who is appointed to stand him ‘in loco parentis’ [in place of a parent], and who not only looks after his interests in everything concerning the University and the lectures, but is always prepared to advise him in any serious case of difficulty and doubt that may trouble him.⁸

Thus, Cambridge tutors, whose first loyalty was directed to their respective colleges, were responsible for the education of each student from entrance to a college to graduation from the University. Tutors assigned readings, helped students prepare for some examinations, and advised ambitious students who wanted to excel at examinations in the choice of private coach. Courses taught by University professors, lecturers, readers, and demonstrators were not compulsory and, in fact, competed with the education provided by college lecturers. Tutors who were also college lecturers, as was common, usually advised their students to attend their own lectures rather than courses taught by University professors and other educators, for the quite understandable reason that their incomes were based on the number of students attending their lectures. Clearly, the increase in the size of the University teaching staff in the last quarter of the nineteenth century presented college lecturers with a serious challenge. J.J. Thomson, a Cambridge student who would become the third director of the Cavendish Laboratory, considered himself lucky to have as his tutor a classicist because “he let me choose the mathematical lectures I attended, whereas if he had been a mathematician he would have made me go to his own lectures.”⁹

Cambridge University’s control over the quality of its undergraduates was exerted through the University examination which, starting in the early eighteenth century, was systematized and held each January in the Senate House. This examination was called the “tripos,” after the three-legged stool on which early Cambridge students sat during disputations to prove their competence.¹⁰ During the

⁸ Ibid., 21. Brackets added.

⁹ J.J. Thomson, *Recollections and Reflections* (New York: MacMillan, 1937), 34.

¹⁰ For the history of the Mathematical Tripos (and Senate House Examination), see W. W. Rouse Ball, *History of the Mathematical Tripos* (Cambridge, 1880) and *History of the Study of Mathematics at Cambridge* (Cambridge, 1889). A short version, “The History of the Mathematical Tripos,” can be found in W. W. Rouse Ball, *Cambridge Papers* (London: Macmillan and Co., 1918), 252–316. See also J. W. L. Glaisher, “The Mathematical Tripos,” *Proceedings of the London Mathematical Society* 18

Leadership and Creativity

A History of the Cavendish Laboratory, 1871-1919

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