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Women and the culture of university physics in late nineteenth-century Cambridge

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> I think you would be amused if you were here now to see my lectures – in my elementary one I have got a front row entirely consisting of young women (some of them not so young neither, as someone says in Jeames' Diary) and they take notes in the most painstaking and praiseworthy fashion, but the most extraordinary thing is that I have got one at my advanced lecture. I am afraid she does not understand a word and my theory is that she is attending my lectures on the supposition that they are Divinity and she has not yet found out her mistake.
>
> Professor J. J. Thomson to Mrs H. F. Reid, 4 November 1886[1]

When Joseph John Thomson used this light-hearted description to brighten up a letter to a family friend, women had been attending physics lectures at the Cavendish Laboratory for four years. Though the picture was designed to amuse the recipient, a married woman, joviality thinly disguised unease. Thomson's previously homogeneous audience had been physically split into two opposing sections with young, male students at the back and older, female students along the front row. Intellectual divisions were also apparent; the women took notes in a different, non-male way, and without the sharpness of a masculine mind they could not understand the content. The message was plain – the women had made a mistake. Their infiltration had been unsuccessful and they did not fit in.

This image of female 'outsiders', oddly positioned and out of place, is encouraged by histories that emphasize the masculinity of Cambridge physics. First, the roots of physics teaching in the Cavendish are shown to be interconnected with the now infamous Mathematics Tripos, a test of physical athleticism and manliness as well as mental agility.[2] In addition, accounts of the quality and nature of research work stress the importance of an inevitably masculine atmosphere, fostered by charismatic laboratory directors James Clerk Maxwell, Lord Rayleigh, J. J. Thomson and Ernest Rutherford.[3] Little attempt has

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1 J. J. Thomson to Mrs H. F. Reid, 4 November 1886, quoted in R. J. Strutt, *Life of Sir J. J. Thomson O.M. Sometime Master of Trinity College, Cambridge*, Cambridge, 1942, 28–9.

2 D. B. Wilson, 'The educational matrix: physics education at early-Victorian Cambridge, Edinburgh and Glasgow Universities', in *Wranglers and Physicists* (ed. P. M. Harman), Manchester, 1985, 12–48; A. Warwick, 'The worlds of Cambridge physics', in *The Physics of Empire* (ed. R. Staley), Whipple Museum for the History of Science, Cambridge, 1994, 57–86.

3 J. J. Thomson *et al.*, *A History of the Cavendish Laboratory, 1871–1910*, London, 1910; A. Wood, *The Cavendish Laboratory*, Cambridge, 1946; E. Larsen, *The Cavendish Laboratory: Nursery of Genius*, London, 1962; G. P. Thomson, *J. J. Thomson and the Cavendish Laboratory*, London, 1964; R. Sviedrys, 'The rise of

been made to see how women fitted into this community built upon masculine ritual and tradition. Though women students had been present in Cambridge in 1874, when the Cavendish Laboratory opened, it was not until the end of the decade that they were permitted to take their place at the workbench. Their presence provides a fascinating, yet neglected area of research. The admission of female students into the Cavendish in 1882 coincided with the removal of celibacy restrictions on fellowships.[4] Until this date, the only women known to Cambridge dons outside their family circle would have been bedders tidying their rooms, and prostitutes attending to their more illicit needs.[5] What expectations were placed on young women working alongside men who were used to receiving only the services of female cleaners and whores?

The absence of work on women in laboratories in this period is indicative of the ways in which Victorian life has been characterized. One dominant ideology is the so-called 'separate spheres' model, a spatial and intellectual division of the sexes. Put simply, men occupied the public sphere, the workplace and positions of office, whilst women's sphere was in the home, an essentially private space. Women who chose to 'break out' from domestic confinement are pictured as pioneers who used education as a route to independence.[6] Attempts to add some fluidity to the model have been made by Martha Vicinus, who acknowledges that the boundaries were 'proper-but-changing'. None the less, as she sees it, women were still fighting to widen their sphere against a masculine framework.[7] Recent trends are to move away from the notion of constraint and see how women crafted spaces for themselves.[8] With this comes the recognition of less explicit methods of exclusion, focusing on places of activity rather than formal legislation.[9]

physical science at Victorian Cambridge', *Historical Studies in the Physical Sciences* (1970), **2**, 127–52; J. G. Crowther, *The Cavendish Laboratory, 1874–1974*, London, 1974; I. Falconer, 'J. J. Thomson and "Cavendish" physics', in *The Development of the Laboratory* (ed. F. A. J. L. James), London, 1989, 104–17; D.-W. Kim, 'J. J. Thomson and the emergence of the Cavendish School, 1885–1900', *BJHS* (1995), **28**, 191–226.

4 R. Macleod and R. Moseley, 'Fathers and daughters: reflections on women, science and Victorian Cambridge', *History of Education* (1979), **8**, 321–33.

5 J. J. Thomson, *Recollections and Reflections*, London, 1936, 34, for the duties of bedders; C. Jackson, *A Cambridge Bicentenary – The History of Legal Practice 1789–1989*, Cambridge, 1990, 177–88, discusses the practices of Cambridge's infamous spinning house, where suspected prostitutes were taken. For a student's view see 'The spinning house of the future', *Cambridge Review* (1891), **12**, 255, a poem lamenting the day when proctors will guard 'Girton girls' from lusty undergraduates instead of protecting male students from street vice.

6 Examples of this genre of history include L. R. Noun, *Strong-Minded Women*, Iowa, 1969; M. Fuller, *Woman in the Nineteenth Century*, New York, 1971; M. E. Bryant, *The Unexpected Revolution: A Study in the History of the Education of Women and Girls in the Nineteenth Century*, London, 1979; P. S. Robertson, *An Experience of Women: Pattern and Change in Europe*, Philadelphia, 1982.

7 M. Vicinus, 'Introduction: new trends in the study of the Victorian woman', in *A Widening Sphere: Changing Roles of Victorian Women* (ed. M. Vicinus), Indiana, 1977, pp. ix–xix.

8 R. Billington, 'The dominant values of Victorian feminism', in *In Search of Victorian Values: Aspects of Nineteenth-Century Thought and Society* (ed. E. M. Sigsworth), Manchester, 1988; A. Vickery, 'Golden age to separate spheres? A review of the categories and chronology of English women's history', *Historical Journal* (1993), **36**, 383–414; A. Winter, 'Harriet Martineau and the reform of the invalid in Victorian England', *Historical Journal* (1995), **38**, 597–616.

9 C. Hall, *White Male and Middle Class: Explorations in Feminism and History*, Cambridge, 1992, makes the point that once political meetings were moved indoors from the street, the automatic participation of men, women and children was broken.

Continuing the move away from confrontation and division, Jeanne Peterson's portrayal of Victorian family life stresses partnership and cooperation.[10] The emphasis has shifted from confrontation to integration.

Drawing on these themes I hope to demonstrate how histories of women in science would benefit from taking a less antagonistic stance. The 'rediscovery' of previously 'invisible' women at the workbench is a subject upon which much useful work can be done. By concentrating on one establishment, the Cavendish Laboratory, the topic neatly ties together debates on the intellectual and physical expectations placed on women situated within the curious culture of Cambridge University.[11] First of all I will set the scene by outlining the position of women in Cambridge and their relationship with the University. Next, the doors to the Cavendish can be opened to examine how women assimilated themselves, becoming part of a team and not interlopers. Finally, a comparison with other sites of science teaching within the University will help contextualize my account. In highlighting ideas of partnership, collaboration and the roles adopted by women students, the culture of Cambridge physics can be reconstructed from a gendered perspective, demonstrating how the Cavendish provided a space where historiographic notions of spheres and boundaries overlap.

PHYSICALITY AND PHYSICS

The arrival of women students at Cambridge University, a traditional, male establishment, during the last third of the nineteenth century, raised many fundamental questions, including the nature of intellectual identity and the physical suitability of women for study. These issues were contentious and highly public, coming at a time when the status of male education itself was being put under close scrutiny.[12] Two contrasting models for the right of women to higher education evolved in the shape of Girton and Newnham Colleges. Whilst we might have expected close links between the two establishments, they were geographically and ideologically distinct. Girton students were housed outside the city boundary, yet expected to follow an identical pattern of study to their male peers. In contrast, Newnham College grew from within the city centre and promoted specially tailored classes for its female students.[13] The emergence of two quite different models should remind us that issues surrounding the right of women to exercise their minds were

10 M. J. Peterson, *Family, Love and Work in the Lives of Victorian Gentlewomen*, Bloomington, 1989.

11 Recent work which recognizes the situated character of knowledge is discussed in A. Ophir and S. Shapin, 'The place of knowledge: a methodological survey', *Science in Context* (1991), **4**, 3–21.

12 Educational ethos is discussed in J. A. Mangan, *Athleticism in the Victorian and Edwardian Public School: The Emergence and Consolidation of an Educational Ideology*, Cambridge, 1981; P. R. H. Slee, *Learning and a Liberal Education: The Study of Modern History in the Universities of Oxford, Cambridge and Manchester 1800–1914*, Manchester, 1986.

13 Hall, op. cit. (9), 82–3, traces the origins of the 'equal or different?' debate to the late eighteenth century; R. McWilliams-Tullberg, *Women at Cambridge: A Men's University – Though of a Mixed Type*, London, 1975, deals with the issues surrounding the formation of Newnham and Girton Colleges, and the conflicting ideals of their founders. This theme has been recently taken up again by G. Sutherland, 'Emily Davies, the Sidgwicks and the education of women in Cambridge', in *Cambridge Minds* (ed. R. Mason), Cambridge, 1994, 34–47.

contested even within the ranks of the educational reformers. Even if one decided that women *did* have a right to come to Cambridge, it was not obvious what a University woman would look or act like.[14] In a place with such important, detailed and explicitly male rituals attached to its learning practices, this was not a trivial point.

Girton College was primarily the brainchild of Emily Davies, though she enjoyed the support of several other influential women including Frances Buss, Dorothea Beale and Barbara Bodichon, all of whom had been instrumental in the setting up of girls' public schools.[15] The initial scheme involved renting a house at Hitchin, half-way between Cambridge and London. Here the first students to arrive in October 1869 were ensured both the privacy necessary for study and freedom from chaperonage. It was not until four years later that the college moved to the outskirts of Cambridge, adopting the name of 'Girton'. Though Miss Davies deliberately housed her students well away from the centre of the University, she was adamant that her girls should follow exactly the same curriculum as their male counterparts, believing that anything different would be classed as second rate.[16] In 1872 three Girtonians were carefully marshalled to and from Cambridge to take Tripos exams on an unofficial basis, the University Senate having rejected a proposal to let women officially sit for the papers. In the public debate that ensued, Miss Davies faced criticism that Girton was 'slavishly copying' the 'faults' of the men's colleges. Nevertheless, fearing that anything different would be regarded as inferior rather than simply an alternative, students at Girton continued to study for the Tripos.

Whilst Emily Davies battled to get her students accepted on equal terms with male undergraduates, a process of negotiation between educational reformers and university professors resulted in the foundation of a second women's college, under the leadership of Anne Jemima Clough.[17] Miss Clough, an active participant in the movement for higher education for women, had previously initiated the North of England Lecture Series. The lectures led to the system of Higher Local Examinations, and by 1869 the scheme was running successfully with over twenty centres in the north of England. The agnostic moral philosopher Henry Sidgwick, ardent promoter of women's education and Fellow of Trinity College, Cambridge, realized that lectures could easily be given in the University city itself, and a series began the very next term. In the autumn of 1871, 74 Regent Street was opened to house five young women from outside Cambridge who wished to attend the lecture series; in 1875, Newnham Hall was opened to cater for the increasing demand for

14 B. Megson and J. Lindsay, in *Girton College 1869–1959: An Informal History*, Cambridge, 1960, 42–3, note that students at the two women's colleges even dressed differently from each other.

15 The formation and early history of Girton College are well documented in B. Stephen, *Emily Davies and Girton College*, London, 1927; Megson and Lindsay, op. cit. (14); M. C. Bradbrooke, '*That Infidel Place' A Short History of Girton College, 1869–1969*, London, 1969. For the educational philosophy behind the Girton regime see D. Bennett, *Emily Davies and the Liberation of Women 1830–1921*, London, 1990; E. Davies, *The Higher Education of Women*, London, 1866; E. Davies, *Women in the Universities of England and Scotland*, London, 1896.

16 Robertson, op. cit. (6), 476.

17 For the formation of Newnham College and the work of its first principal see B. A. Clough, *A Memoir of Anne Jemima Clough*, London, 1897; A. Gardner, *A Short History of Newnham College*, Cambridge, 1921; M. A. Hamilton, *Newnham, an Informal Biography*, London, 1936. A less complementary picture of Miss Clough is given by R. N. Soffer, 'Authority in the university: Balliol, Newnham and the new mythology', in *Myths of the English* (ed. R. Porter), Cambridge, 1992, 192–215.

residence. Those women who wanted to could study for Tripos examinations, but unlike the regime at Girton, this was by no means a requirement of their residence.

Given that the women's colleges were based upon two different models of learning, we should not be surprised that there was no uniform policy within the University on the acceptance of young ladies alongside the male students. Whilst some professors were keen to encourage programmes of higher education for women, there was little consensus over whether teaching should be mixed-sex or segregated. Since Newnham had evolved from a scheme separate from the University, there was no pressure on students to follow the same syllabus as students in the male colleges. Many residents felt content to attend the lectures given by professors of the University in connection with the original scheme of higher education for women.[18] However, besides these specially tailored courses, a large number of University lectures were, by special permission, gradually opened to women. By 1873, twenty-two out of thirty-four university professors at Cambridge admitted women to their regular classes, and on this informal basis access continued to grow.

The gradual introduction of mixed-sex teaching in the University occurred alongside other fundamental educational changes. Just as the appearance of female students echoed current debates over the suitability of women to higher education, so changes in science teaching reflected a national movement towards institutionalization of science.[19] Opened in 1874, the Cavendish Laboratory was built to teach heat, light, electricity and magnetism to students of mathematics, forging links between the cultures of physics and physicality.[20] Athleticism fostered on the rugby pitch was a key feature in the Mathematics Tripos, which was more a test of stamina and solid ability than mathematical ingenuity. Getting half-way to completing each Tripos paper was considered a feat in itself and students were trained rather than taught to reach the high level of physical and mental discipline required. The central part of the training process was intense competition, and students employed 'concentration, accuracy and mobility' in their gallop to finish top of the order of merit.[21] Success in mathematics and physical science consequently required training of the mind and body.

The importance of this bodily economy to scientific culture meant that gender and sex differences were central to all discussions on the suitability of women to study physical science. Arguments based on conservation and transformation of energy bolstered claims that excessive mental and physical exertions were physiologically detrimental to the 'weaker' sex.[22] Writing to her mother at the beginning of her first term at Newnham

18 Details of these lectures and practical classes were published in the *Cambridge University Reporter*.

19 The increasing importance of university teaching laboratories has been discussed in G. Geison, *Michael Foster and the Cambridge School of Physiology*, Michigan, 1970; R. Sviedrys, 'The rise of physics laboratories in Britain', *Historical Studies in Physical Science* (1976), **7**, 405–36; G. Gooday, 'Precision measurement and the genesis of physics teaching laboratories in Victorian Britain', *BJHS* (1988), **23**, 25–52. Falconer, op. cit. (3), 104–17, examines the relationship between changes in Cambridge physics and the work carried out in the Cavendish.

20 Thomson, op. cit. (5), 102.

21 Thomson, op. cit. (5), 58.

22 C. E. Russett, *Sexual Science: The Victorian Construction of Womanhood*, Cambridge, MA, 1984; E. Showalter, *The Female Malady: Women, Madness and English Culture, 1830–1980*, London, 1987, 121–7, links mental overstrain to a potential threat to the reproductive system and vice versa.

College in 1889, Catherine Durning Holt commented that she had been advised by the Principal to 'read either a little History or Literature instead of going in completely for Physics'.[23] Students themselves also worried about rigour and the tendency of even 'strong' girls to have a breakdown. Most preferred to get a low place and a more general education instead of going for 'honours in the Science Tripos'.[24] Meanwhile, tennis courts and hockey pitches were provided at both women's colleges to fulfil the demand for competitive sport.[25] Those women who did possess both great physical and intellectual powers faced speculation in the medical press over the masculinity of their bodies as well as their minds.[26] Never short of a comment, the satirical magazine *Punch* warned that women who studied mathematics would be incapable of engaging in polite conversation with members of the opposite sex:

> The Woman of the Future! She'll be deeply read, that's certain,
> With all the education gained at Newnham or at Girton;
> She'll puzzle men in Algebra with horrible quadratics,
> Dynamics and the mysteries of higher mathematics.[27]

The stereotyped Victorian image of a feminine angel in the home was clearly incompatible with muscularity and physical robustness, which were viewed as exclusively masculine qualities. Women physicists would be recognized as either frail specimens of humanity or freaks of nature, both incapable of fulfilling the ideal of womanhood. In opening their doors to students from Newnham and Girton, would the Cavendish Laboratory become a refuge for defeminized outcasts and oddballs?

FRAMING THE INVISIBLE

In 1882 when women were admitted for the first time to the Tripos examinations, it was at last decided, following a suggestion of Lord Rayleigh, that all classes and demonstrations should be opened to students of the Newnham and Girton Colleges.[28] However, once across the laboratory threshold, it becomes problematic for historians to follow them inside. How is it that this group of frail specimens and unwomanly freaks of nature could escape our gaze (Figure 1)? Membership of the University was still an exclusively male privilege and its relationship with women students or researchers remained ambiguous. Women are not mentioned in any financial records relating to the Cavendish Laboratory because they were barred from University employment until 1923.[29] Instead, researchers have had to rely on the *History of the Cavendish Laboratory, 1874–1910* as their official source. Published as a celebration of the Laboratory's work in 1910, the record lists 'those

23 C. D. Holt, *Letters from Newnham College 1889–1892* (ed. E. O. Cockburn), private print, Cambridgeshire Collection, Cambridge Central Library, 13.

24 Holt, op. cit. (23), 41.

25 K. McCrone, *Sport and the Physical Emancipation of Women, 1870–1914*, London, 1988, 21–58.

26 *Lancet* (1869), 511; A. Kenealy, 'Woman as an athlete', *Nineteenth Century* (1899), **45**, 636–45.

27 *Punch*, 10 May 1884, 225.

28 Crowther, op. cit. (3), 91.

29 Hamilton, op. cit. (17), 182–3.

Figure 1. A practical class in the Cavendish Laboratory *c*. 1900. Note how the picture's focus on the central male figures sidelines the 'ghostly' female students. Reproduced by courtesy of the University of Cambridge, Cavendish Laboratory, Madingley Road, Cambridge.

who have carried out researches at the Cavendish Laboratory' as an appendix. The list does contain women's names but, as it was compiled by a retrospective questionnaire sent to past workers, inaccuracies are likely, relying as it does on hazy memory.[30] Faced with these difficulties, many studies either exclude women completely or fit them into an inappropriate framework. For example, David Wilson omits women from his analysis of 'Workers in the Cavendish Laboratory, 1875–1900' on the grounds that their 'educational and career expectations and patterns differed from men's'. His justification for this is that only two of the women he counted had sat Tripos examinations and neither had specialized in physics.[31] His argument on the changing culture of Cambridge physics consequently ignores the link between a change in ethos at the Cavendish and the increasing heterogeneity of researchers. On the other hand, Roy Macleod and Russell

30 Thomson *et al*., op. cit. (3), 324–34.

31 D. B. Wilson, 'Experimentalists among the mathematicians: physics in the Cambridge Natural Sciences Tripos, 1851–1900', *Historical Studies in the Physical Sciences* (1982), **12**, 325–71.

Moseley's study explicitly focuses on women. However, by confining their gaze to those 'who read for the Natural Sciences Tripos 1880–1916', they make the assumption that women entered physics along the same route as male undergraduates.[32] Neither approach is particularly instructive.

Lack of a suitable framework, or failure to acknowledge the need for one, has led to contradiction and mistakes in the secondary literature. Most recently, Dong-Won Kim included the Australian 'F. Martin' in his list of 'non-Cambridge men' who entered the Cavendish as guests; Florence Martin would not have been amused by the description.[33] Moreover, there is no consensus on the numbers of women present in the Cavendish or how we should count them. Although the official history lists seven female 'workers', Wilson counted only six before deciding to ignore them all anyway.[34] The authors of the most recent Cavendish prosopography went one better and produced a grand total of nine, adding Margaret Isabella Gardiner and Anna Bateson to the list.[35] They chose not to identify these two as undergraduate students, nor to mention Catherine Durning Holt, later Lady Dampier, who met her future husband in a practical class. If numbers are to be counted and lists of names drawn up, it is imperative that we construct a meaningful framework, otherwise the results are worthless.

This study concentrates on research students rather than undergraduates for two main reasons. First, there is more information available regarding those who worked at the Cavendish at their own initiative. Secondly, the increased ambiguity of the status of 'researcher' allowed women more scope in fashioning their role. Whilst female undergraduates entered the laboratory only to attend timetabled lectures and practical courses, there were no similar time constraints on those carrying out original research. Instead, women had to work even harder to justify their place in an already crowded work area and negotiate a relationship with male colleagues.

Since there was no prescribed route for aspiring female physicists to follow, influence and support from family members effectively shaped their lives. Patterns of behaviour between fathers and daughters, uncles and nieces, brothers and sisters became a model for gendered working relationships.[36] Pnina Abir-Am and Dorinda Outram have claimed that the nature of the home environment was of the utmost importance in determining the career patterns of women, those families with a 'decreased capacity for social conformity' being more likely to allow their daughters a greater degree of educational freedom.[37] This analysis fits well with portrayals of Philippa Garrett Fawcett, daughter of Henry Fawcett, Fellow of Trinity College and Postmaster General to Gladstone, and Millicent Fawcett, leading 'suffragist' and member of Newnham College Council. Philippa Fawcett's home life was noted as being 'progressive' owing largely to her mother's insistence on self-

32 Macleod and Moseley, op. cit. (4), 322.

33 Kim, op. cit. (3), 208.

34 Wilson, op. cit. (31), 350.

35 M. Price, J. A. Hughes and S. Schaffer, 'The Cavendish Laboratory: Introduction to Prosopography', unpublished typescript, Whipple Museum for the History of Science, Cambridge, 1991.

36 Macleod and Moseley, op. cit. (4), 333, for the tendency for daughters to follow in their father's footsteps.

37 P. G. Abir-Am and D. Outram, 'Introduction', in *Uneasy Careers and Intimate Lives: Women in Science 1789–1979* (ed. P. G. Abir-Am and D. Outram), London, 1987, 1–16.

reliance and freedom of thought.[38] Ida Freund was raised by her maternal grandmother in Vienna and brought to England under the care of her uncle, the violinist Ludwig Strauss. Having enjoyed the benefit of a state education in Austria she continued to find sympathy with every legitimate effort to promote the social and educational progress of women.[39] Similarly, it is likely that Helen Klaassen, daughter of an immigrant Prussian businessman, found that her Germanic family roots contributed to a partial rejection of English social conventions.[40]

Meanwhile, Jeanne Peterson has argued that the Paget family, headed by George Paget, Regius Professor of Medicine at Cambridge, belonged to a social set comprising the 'most conventional… oriented towards the status quo'. His daughter Rose's involvement in science and her presence at the Cavendish were just a part of a pattern of intellectual life common to Victorian gentlewomen.[41] Sarah Jane Dugdale Harland, born in Salford to the respected physician Thomas Harland, no doubt belonged to a similar set based in the North of England.[42] The model can be extended to include both Eleanor Balfour Sidgwick, wife of moral philosopher Henry Sidgwick and later Principal of Newnham College, and Florence Martin, eleventh child of Sir James Martin, Premier of New South Wales and later Chief Justice.[43] Their inherited family wealth allowed them to indulge their interests by widening their knowledge of mathematics and physics without incurring the wrath of society.

Families not only provided financial backing, but could also provide intellectual support. Given the fragmented nature of girls' education, even at the end of the nineteenth century, it is hardly surprising that the home remained a source of intellectual stimulation and perhaps inspiration. Philippa Fawcett's triumph in the Mathematics Tripos, obtaining a good 13 per cent (400 marks) ahead of the recognized senior wrangler, fitted easily into her family history of mathematical excellence. Her father had been seventh wrangler in Part I in 1856 and her aunt, Alice Garrett, had been a child prodigy with a special talent for mathematics. Following the family tradition, Alice's son and Philippa's cousin, Philip Cowell, went on to become senior wrangler in 1892. On reaching Cambridge, Philippa needed no introduction to the coaching procedure attached to the Mathematics Tripos, having been tutored from the age of fifteen by a friend of her father's.[44] Eleanor Sidgwick

38 The ethos of the Fawcett household is discussed in R. Strachey, *Millicent Garrett Fawcett*, London, 1931; D. Rubinstein, 'Victorian feminists: Henry and Millicent Garrett Fawcett', in *The Blind Victorian: Henry Fawcett and British Liberalism* (ed. L. Goldman), Cambridge, 1989, 71–92. For Philippa's close relationship with her mother see 'Millicent Garrett Fawcett and her daughter', *Review of Reviews* (1890) **2**, 17–23.

39 *Newnham College Register*, *1871–1971*, 2 vols., London, 1979, **i**, 7; *Girton College Register*, *1869–1946*, Cambridge, 1948, 21; Obituary of Ida Freund, *Girton Review* (1914), **41**, May term.

40 Obituary of H. M. Klaassen, *Geological Magazine* (1910), **47**, 191.

41 Peterson, op. cit. (10), 57.

42 *Newnham College Register*, *1871–1971*, 2 vols., London, 1979, **i**, 57.

43 For Eleanor Sidgwick see *Newnham College Register*, *1871–1971*, 2 vols., London, 1979, **i**, 1; E. Sidgwick, *Mrs Henry Sidgwick – A Memoir*, London, 1938; H. Fowler, 'Eleanor Mildred Sidgwick, 1845–1936', in *Cambridge Women: Twelve Portraits* (ed. E. Shils and C. Blacker), Cambridge, 1996, 7–28. Florence Martin's family background can be found in *Australian Dictionary of Biography 1891–1939*, Melbourne, 1986, x, 427.

44 Strachey, op. cit. (38), 14; S. Siklos, 'Philippa Fawcett and the Mathematics Tripos', unpublished pamphlet, Newnham College Library, Cambridge, 1990; *Cambridge University Reporter* (1892), **940**, 978.

gained an enthusiasm for mathematics from her mother's teaching, and then helped her younger brother as he struggled with his own lessons.[45] Helen Klaassen may have been encouraged by the activities of her father, active member of the Geologists' Association and Fellow of the Geological Society, who no doubt carried out his microscopical investigations for Croydon Natural History and Microscopical Club in the family home.[46] Rose Paget's education was more directly shaped by her father, who suggested suitable topics and ensured she possessed the most relevant books. When Rose accompanied her mother and sister on holidays to Wales, he posted 'appropriate texts' from Cambridge to the family holiday home.[47] Whilst these women undeniably based their learning on their own interests and a keenness to study, education was ultimately guided from within the family.

On occasion the thin line between guidance and interference was breached. Ida Freund, sent to Girton College by her uncle, was initially opposed to the idea. Despite her objections to the scheme she was persuaded to enrol in the Natural Sciences Tripos, completing Part II with a First and then staying in Cambridge to carry out her own research.[48] When Philippa Fawcett was offered the Marion Kennedy Scholarship from Newnham College, in order to support her independent research work, her mother openly disapproved. In a letter to Philippa written in May 1891, Mrs Fawcett strongly urged her daughter to reject the studentship and to become articled in a law office. The letter suggests Philippa should work with Sam Garrett, Millicent's eldest brother. Law, she believed, would be 'a magnificent profession for women' and one to which Philippa's temperament would be well-suited. Indeed, she even contemplated writing to Miss Clough on her daughter's behalf: 'Would you like me to write to Miss Clough?…I shall not say anything to her of future plans for you, only that you had decided that it was best *not* to apply for the studentship.'[49] Though Millicent Fawcett is generally pictured as an advocate of increased freedoms for women in the nineteenth century, she perceived the differences that science and law presented as career opportunities. Was the controlled environment of a solicitor's office a preferable space for women? Or perhaps she was ambitious for her daughter and recognized the limitations of research as a truly independent career?

Millicent Fawcett's worries that her daughter would not shine individually in academia were entirely justifiable. In many respects, patterns of work in the Cavendish Laboratory reflected the norms of everyday working life, stressing partnerships instead of individuals. 'Certainly there is something unique', one of Thomson's former students noted, 'about the relationship between the professor and the student who sets out on his research career under him'.[50] This relationship was often linked to the family unit, a well-documented tradition in histories of women scientists.[51] Eleanor Sidgwick worked in partnership with

45 Sidgwick, op. cit. (43), 8–9 and 21.

46 Obituary, op. cit. (40).

47 Peterson, op. cit. (10), 38–9.

48 Obituary, op. cit. (39).

49 Letter from Millicent Garrett Fawcett to Philippa Fawcett, May 1891, Fawcett Library, London Guildhall University, 7/MGF1/17.

50 E. V. Appleton's obituary of J. J. Thomson, *Nature* (1940), **146**, 354.

51 Caroline Herschel provides an example of a woman's place beside her brother, M. B. Ogilvie, 'Caroline Herschel's contributions to astronomy', *Annals of Science* (1975), **32**, 149–61; M. Pycior, 'Marie Curie's "Anti-Natural Path": time only for science and family', in Abir-Am and Outram, op. cit. (37), 191–215, describes how

her brother-in-law, Lord Rayleigh, then Director of the laboratory.[52] Florence Martin travelled to Cambridge from Sydney with a note of recommendation from family friend and former Cavendish worker Richard Threlfall. On arrival, she lodged with Thomson and his wife, the supervisor in the laboratory reappearing as her surrogate father at the dinner table.[53] Some female researchers went one step further, choosing to 'breach academic propriety' and form romantic liaisons with their mentors.[54] Rose Paget's investigations into soap films came to an abrupt halt in December 1889 on her engagement to Thomson. They were married in January 1890 and she adopted the new position of laboratory hostess.[55] Sarah Harland also met her future husband William Shaw, laboratory demonstrator and then lecturer in experimental physics, at the workbench. She continued to assist with his meteorological investigations even after their betrothal in 1885.[56] Marriage formalized the male–female partnership, replacing the image of the supervisor as a protective father-figure with one of a collaborator. Nevertheless the exact nature of partnerships remained ambiguous.

COLLABORATION AND CREDIT

Just as their male colleagues strove to build strong reputations out of published material, so women needed to disseminate the results of their work. The mechanisms whereby this could be achieved were naturally different from those employed by their male contemporaries. Indeed, as Barbara Becker has shown in her work on William and Margaret Huggins, the title of 'assistant' as applied to women often disguised the creative and innovative input that they may have contributed to a particular project.[57] Failure to acknowledge the work of assistants or technicians is an especially crucial issue with regard to women, since they were usually afforded these lower status roles. The name at the top of a paper often disguised the actual labour involved in the production of scientific knowledge.[58] Reference works that catalogue published papers ignore all scientific activity that did not appear in journals, thus privileging a particular form of participation. Mary

Marie Curie worked alongside her husband in the laboratory as does M. B. Ogilvie, 'Marital collaboration: an approach to science', 104–25, in the same collection of essays. See also H. M. Pycior, N. G. Slack and P. Abir-Am (eds.), *Creative Couples in the Sciences*, New Brunswick, 1996.

52 R. J. Strutt, *John William Strutt: Third Baron Rayleigh*, Cambridge, 1924, 108.

53 J. J. Thomson to Richard Threlfall, 28 October 1893, Cambridge University Library, J. J. Thomson Correspondence, Add. MSS 7654, T30, and 20 April 1894, T32. See also A. S. Eve, *Rutherford*, Cambridge, 1939, 15.

54 The disapproval felt by female students towards the behaviour of their peers is recorded in A. Phillips (ed.), *A Newnham Anthology*, Cambridge, 1979, 46.

55 G. P. Thomson, op. cit. (3), 77; J. J. Thomson to Richard Threlfall, 1 January 1890, Cambridge University Library, J. J. Thomson Correspondence, Add. MSS 7654, T24.

56 R. T. Glazebrook, 'The Rayleigh period', in *A History of the Cavendish Laboratory 1871–1910*, London, 1910, 40–75.

57 B. J. Becker, 'Dispelling the myth of the able assistant: Margaret and William Huggins at work in the Tulse Hill Observatory', in Pycior, Slack and Abir-Am, op. cit. (51), 98–111.

58 S. Shapin, 'The house of experiment', *Isis* (1988), **79**, 373–404; and Hannah Gay, 'Invisible resource: William Crookes and his circle of support, 1871–81', *BJHS* (1996), **29**, 311–36.

Creese's paper on nineteenth-century British women chemists is just one example of a woman-oriented study that relies on a male-oriented framework. Her list of women who contributed to research is confined to 'those who were authors or co-authors of original work in the chemical sciences'. Eleanor Sidgwick is included in the section on electrochemistry by virtue of her contribution to 'a remarkable series of investigations' published jointly with Rayleigh in the early 1880s.[59] Florence Martin, Philippa Fawcett, Sarah Harland and Helen Klaassen, all of whom carried out electrochemical experiments in the Cavendish throughout the late 1880s and 1890s, are excluded.

During the period of my study, the Cavendish was noted as a centre of excellence for a variety of research projects. The type of research done was, not surprisingly, influenced by the character and interests of the man at the helm. Whilst Rayleigh was professor of experimental physics from 1879 until 1884, workers were engaged in determining electrical standards of resistance in a highly disciplined regime.[60] Their search for values can be compared with the 'virtuous labour' exacted by women slaving in the 'laboratories of fashion' in the industrialized textile industry.[61] Under Thomson, the scope of projects widened to include work on electrolysis, optics, heat and magnetism. An examination of the nature of work carried out by female students will show how women actually positioned themselves in regard to the day-to-day laboratory activities. This can then be applied to then-contemporary arguments re the suitability of women to certain types of work.

Throughout the 1880s, Eleanor Sidgwick collaborated with her brother-in-law Rayleigh on topics ranging from the specific resistance of mercury to the determination of the absolute value of the ohm.[62] She was noted for her 'patient accuracy and neatness of hand', keeping the notebooks on the later electrical measurements and checking most of the long arithmetical computations, as well as participating in the observations themselves.[63] Whilst the work may have been invaluable to the standards committee, it was hardly exciting, a fact acknowledged by both Rayleigh and Sidgwick. 'The determination of the specific resistance of mercury', they wrote, 'is simple enough in principle, though the execution is somewhat tedious'.[64] Continuing on the theme of tedium, their next paper carried a warning to those who might wish to replicate the experiment: 'Table 1 … gives the results

59 M. R. S. Creese, 'British women of the nineteenth and early twentieth centuries who contributed to research in the chemical sciences', *BJHS* (1991), **24**, 275–305. For Eleanor Sidgwick's work on electrochemistry see R. J. Rayleigh, and E. M. Sidgwick, 'On the specific resistance of mercury', in *Philosophical Transactions of the Royal Society of London* (1883), **174**, 173–85 and 'On the electro-chemical equivalent of silver, and on the absolute electromotive force of Clark cells', ibid. (1884), **175**, 411–60.

60 C. Smith and M. N. Wise, *Energy and Empire: A Biographical Study of Lord Kelvin*, Cambridge, 1989, 684–98; S. Schaffer, 'Late Victorian metrology and its instrumentation: a manufactory of ohms', in *Invisible Connections* (ed. R. Bud and S. Cozzens), Washington, DC, 1992, 23–56.

61 William Acton, 1866, quoted in S. Marcus, *The Other Victorians: A Study of Sexuality and Pornography in Mid-Nineteenth-Century England*, London, 1966, 5–6.

62 Rayleigh and Sidgwick, 'Mercury' op. cit. (59), 173–85; and 'Experiments by the method of Lorentz for the further determination of the absolute value of the British Association unit of resistance, with an appendix on the determination of the pitch of a standard tuning fork', *Philosophical Transactions of the Royal Society of London* (1883), **174**, 295–322; and 'Silver', op. cit. (59), 411–60.

63 Strutt, op. cit. (52), 108.

64 Rayleigh and Sidgwick, 'Mercury', op. cit. (59), 174.

of a laborious series of determinations.' Praised highly for her bodily work inside the Cavendish, Eleanor Sidgwick developed her spiritual interests outside the laboratory. A leading member of the Psychical Society, she sought evidence for a disembodied afterlife, an existence of pure intellect or mind.[65] In the 1890s, women who had graduated from a university ladies' college were employed as computers at Greenwich Observatory to do jobs previously undertaken by teenage boys. The experiment was discontinued in 1896.[66] Having entered the masculine world of Cambridge physics, Sidgwick's participation in Rayleigh's experiments typified the activity at which women were supposed to excel – repetitive, routine, well-mannered and aesthetically pleasing.[67] Pursuit of the disembodied could occur only outside the laboratory.

The situation for women changed considerably in December 1884 when, much to his own surprise, Thomson was appointed Director of Experimental Physics.[68] His research interests differed from Rayleigh's, as did his attitude towards intellectual women. Whilst Rayleigh opened classes at the Cavendish to women on *equal* terms with men in 1882, Thomson was of the opinion that they should be following a different – perhaps easier – programme of work. Thomson voiced his opinion that women should not attend more advanced classes in a letter to his friend and colleague Richard Threlfall in 1887. The women 'always do very well in the first [part] of the Tripos', he observed, 'but make an awful hash of the second, in fact I think in nineteen cases out of twenty they had better not attempt it'.

Given Thomson's conviction that women did not possess mental faculties equivalent to those of men, it is not surprising to find that under his direction, most female researchers found themselves engaged in electrolytic experiments. These experiments were generally popular in the Cavendish because they were related to Thomson's interests and were relatively easy to perform: ideal subject matter for women.[69] Despite the uncomplicated nature of the work, women were often assisted in their labours, though the amount of help they required varied widely. In a letter from Lord Kelvin to J. J. Thomson in 1887, Kelvin explicitly thanked 'Miss Harland for taking so much trouble for me in the electrolytic observation'.[70] Here, the student was explicitly given credit for performing the experiment. Helen Klaassen looked at electric resistance curves in sulphuric acid at varying temperatures, a topic that had been 'suggested' to her by Thomson.[71] Philippa Fawcett

65 J. Oppenheim, *The Other World: Spiritualism and Psychical Research in England, 1850–1914*, Cambridge, 1985, 120. A. Owen, *The Darkened Room: Women, Power and Spiritualism in Late Victorian England*, London, 1989, examines women's involvement in spiritualism and the subversion of gendered power relations.

66 A. J. Meadows, *Greenwich Observatory. Volume 2: Recent History (1836–1975)*, London, 1975, 14.

67 Caroline Herschel was praised for her diligence and accuracy not her brilliance or genius, Ogilvie, op. cit. (51), 149–61.

68 By his own admission, Thomson was not the best experimenter and on learning of his new appointment declared that he 'felt like a fisherman who with light tackle had casually cast a line in an unlikely spot and hooked a fish much too heavy for him to land'. Thomson, op. cit. (5), 98.

69 Kim, op. cit. (3), 210.

70 William Thomson to J. J. Thomson, 7 June 1885, J. J. Thomson Correspondence, Cambridge University Library, Add. MSS 7654, K6.

71 H. G. Klaassen, 'The effect of temperature on the conductivity of solutions of sulphuric acid', *Proceedings of the Cambridge Philosophical Society* (1891), **7**, 137–41.

examined the electric strength of mixtures of nitrogen and hydrogen, a set of experiments that again was 'undertaken at Professor Thomson's suggestion'.[72] The implication is that Thomson had the initial thought, but the women were able to perform the experimental work themselves, largely unaided. Florence Martin found herself 'acting under Professor J. J. Thomson's directions' whilst she looked at expansion produced by electric discharge.[73] This implies a more direct role for Thomson as mentor and guide, not just the instigator.

A further example of the gendered politics of collaboration in scientific work is provided by papers published by Florence Martin. Before moving to England, she had been working with Richard Threlfall, one of Thomson's brightest ex-students, as an unpaid researcher at the University of Sydney.[74] A paper detailing their work was subsequently presented to the Royal Society and published in the *Philosophical Magazine* with Martin recognized as an 'assistant'.[75] On her return to Australia, she was acknowledged as 'co-author' in her last published paper, though the hierarchy of contributors was again made plain: 'By R. Threlfall, M.A., Professor of Physics in the University of Sydney, and Florence Martin'.[76] The degree and university position held by Threlfall were exclusively male marks of status.

Sometimes the contribution was not acknowledged at all. William Shaw's paper 'On the atomic weights of silver and copper' was completed, according to Glazebrook, 'with Mrs Shaw's assistance'.[77] There was no acknowledgement by Shaw on the paper, but he did mention results of experiments communicated to the Electrolysis Committee of the British Association that were 'carried out at the Cavendish Laboratory under my direction'.[78] Though he failed to mention any names, we can assume he was directing his young wife.

VISIBLE BODIES

If research contributions by women at the Cavendish remained relatively invisible, their bodily presence was discussed with enthusiasm. This is hardly surprising, given the widespread speculation over masculinized 'oddballs' and mentally exhausted invalids. Did women ape the manly attitudes of their peers who had been bred on a culture of athleticism, or did they overemphasize their femininity by adopting frivolous costumes? With no strong role model it was uncertain as to what a female physicist should look like. The appearance of individuals had as much to do with their family background as with their own mental faculties.

72 P. G. Fawcett, 'The electric strength of mixtures of nitrogen and hydrogen', *Proceedings of the Royal Society of London* (1894), **26**, 263–71.

73 F. Martin, 'Expansion produced by electric discharge', *Proceedings of the Cambridge Philosophical Society* (1895), **9**, 11–16.

74 *Australian Dictionary of Biography 1891–1939*, 14 vols., Melbourne, 1986, **x**, 427.

75 R. Threlfall, 'On an approximate method of finding the forces acting in magnetic circuits', *Philosophical Magazine* (1894), **38**, 89–110.

76 R. Threlfall and F. Martin, 'A contribution to the study of oxygen at low pressures', *Proceedings of the Royal Society of New South Wales* (June 1897), 79–82.

77 Glazebrook, op. cit. (56), 72–3.

78 W. N. Shaw, 'On the atomic weights of silver and copper', *Philosophical Magazine* (1887), **23**, 138.

Figure 2. Newnham College teaching staff in formal pose, 1896. Back row: Helen Klaassen (second from left); front row: Ida Freund (third from left), Eleanor Sidgwick (fifth from left), Philippa Fawcett (far right). Reproduced by courtesy of the Principal and Fellows of Newnham College, Cambridge.

Ida Freund, who partially supported her research into physical chemistry by teaching practical science at Newnham, was described by one student as 'a jolly stout German, whose clothes are falling in rags off her back'.[79] Her vast girth, antithetical to the fashionably tiny waist, was noted by Thomson. 'Miss Freund is about twice the size she was when you were here to make her run about', he commented in a letter to Threlfall. 'If she increases much further we shall have to widen the doors.'[80] The prospect of Ida Freund sprinting up and down the corridors to lose weight was highly unlikely: she had lost a leg in a cycling accident in her youth and relied on a wheelchair for getting around.[81] If Thomson, himself a successful product of Cambridge's wrangler culture, was looking for a new recruit to athleticism, he could hardly have chosen a less suitable candidate.

In her appearance, Helen Klaassen did little to refute the earlier spurious claims of *Punch* magazine that higher education would lead to the un-sexing of women. At first glance, it would appear that their prophecies of manly women intellectuals were vindicated:

79 Holt, op. cit. (23), 11.

80 J. J. Thomson to Richard Threlfall, 7 August 1887, Cambridge University Library, J. J. Thomson Correspondence, Add. MSS 7654, T19.

81 Creese, op. cit. (59), 287.

Figure 3. Newnham College teaching staff posed informally in the orchard, 1896. From left to right: Philippa Fawcett (fourth, seated), Eleanor Sidgwick (seventh), Helen Klaassen (eighth), Ida Freund (ninth). Reproduced by courtesy of the Principal and Fellows of Newnham College, Cambridge.

O pedants of these later days who go on undiscerning,
To overload a woman's brain and cram our girls with learning,
You'll make a woman half a man, the souls of parents vexing,
To find that all the gentle sex this process is unsexing.[82]

Two photographs of Newnham teaching staff taken in 1896 (Figures 2 and 3) present her as a formidable, unsmiling character. Her clothes are very masculine in style – she is wearing a waistcoat and tie. The leg-of-mutton shoulders on her 'tailor-made' jacket artificially broaden her shoulders, presenting an illusion of muscularity beneath the cloth. Conversely, Philippa Fawcett, who appears in the same photographs, is the epitome of the Victorian female image. She has chosen not to adopt the new trend towards the 'two-piece' blouse and skirt, the female equivalent of a lounge suit.[83] Her dress is simple, yet flatteringly feminine and her posture on both pictures demonstrates suitable poise. In fact her 'womanly' appearance and decorum were almost the realization of Mr Punch's fictitious 'sweet girl graduate'.[84] This was the result of systematic self-fashioning, according to the first principal of Newnham College, Miss Clough, who wrote:

82 *Punch*, 10 May 1884, 225.

83 For a thorough discussion on trends in late Victorian clothing see A. Adburgham, *Shops and Shopping 1800–1914: Where and in What Manner the Well-Dressed Englishwoman Bought her Clothes*, London, 1981, 83–265; P. Byrde, *Nineteenth Century Fashion*, London, 1992.

84 C. Rover, *The Punch Book of Women's Rights*, London, 1967, 57.

> When Miss Fawcett came to Newnham, she knew that if there were the remotest pretext, even the most innocent, it would be seized upon by all the silly scribblers who try to make out that the women's colleges are peopled by a sort of impossible race of eccentrics.[85]

Whilst Helen Klaassen's costume hinted at the athletic body beneath, it was actually Philippa Fawcett who relished the chance to race across a muddy field with Newnham's hockey team.[86] Her choice of feminine dress demonstrated an awareness both of the traps of her position and of the scope for fashioning her own place in an uncertain environment.

For Rose Paget, appearance was extremely important. As a young research student carrying out experiments into soap films, inconspicuousness was acceptable. As Mrs J. J. Thomson, her public role came complete with a new set of standards of behaviour. William Bragg boasted about the acquisition of a foot bellows from 'a young lady researcher', when she was temporarily absent from her bench, leaving her 'bowed over her desk in floods of tears'.[87] He would have had to treat the professor's wife with greater respect. One of the 'duties' undertaken by Rose Thomson was the entertainment of her husband's colleagues, many of whom she would also have met before her marriage.[88] On lunching with the Thomsons shortly after arriving in Cambridge, Ernest Rutherford described Rose as 'a tall, dark woman, rather sallow in complexion, but very talkative and affable'.[89] Shortly afterwards, at a science conversazione held in 1896, in honour of a building extension to the Cavendish, Rutherford again commented 'Mrs J. J. looked very well and was dressed very swagger and made a very fine hostess.'[90] The 'sallow' young woman who chatted to research students across the dinner table transformed herself into a bold, confident mistress of ceremonies when the Cavendish displayed itself to the public. As Mrs Thomson, Rose also became guardian of her husband's image, as well as her own. On one occasion, she reputedly telephoned the laboratory to check that he was not wearing a pair of pyjamas, having discovered his trousers on the bedroom floor. In fact Thomson was suitably attired in a new pair of trousers, a purchase previously unknown to his wife.[91] Although Rose Thomson's contribution to actual scientific experimentation ceased on her marriage, she accepted new responsibilities to assist her husband in day-to-day management of the laboratory.

The husband and wife partnership of the Thomsons was also visible in the running of the Cavendish Physical Society, a fortnightly seminar held during term time. Research students and lecturers met together either to discuss recently published scientific papers, or to present their own results to a relatively friendly audience, a half-way house before critical review by anonymous referees.[92] The Society has been heralded as the first of its

85 *Pall Mall Budget*, 12 June 1890, 1.

86 McCrone, op. cit. (25), 38.

87 Quoted in D. Phillips, 'William Lawrence Bragg', *Biographical Memoirs of Fellows of the Royal Society* (1979), **25**, 84.

88 Strutt, op. cit. (1), 35.

89 Eve, op. cit. (53), 15.

90 Eve, op. cit. (53), 30.

91 This anecdote is recounted in Larsen, op. cit. (3), 28.

92 The Society's aims are discussed in J. J. Thomson, 'Survey of the last twenty-five years', in *A History of the Cavendish Laboratory 1871–1910*, London, 1910, 90: L. R. Wilberforce, 'The development of the teaching of physics', in the same volume, 270–1; Wood, op. cit. (3), 25; G. P. Thomson, op. cit. (3), 91.

kind in England, a key step in the development of the laboratory's research tradition. However, despite its historical importance, accounts of its establishment are largely inaccurate. The formation of the Cavendish Physical Society is usually put at 1893, the date 'recollected' by Thomson as he 'reflected' on a lifetime of physics in 1936.[93] Thomson's memory has seldom been challenged on this point, though primary evidence actually puts the first meeting two years earlier.[94]

Meetings were held at the end of the afternoon in the Cavendish lecture room, the venue for undergraduate instruction described by Thomson at the start of this paper, yet there are no references to the audience being spatially segregated. Instead, the explicit division of ladies at the front and gentlemen at the back is replaced by descriptions of strictly gendered roles. As official Cavendish hostess, Rose Thomson was responsible for providing refreshments at the start of each meeting, sometimes enlisting other female researchers to assist her. These women are described as tea ladies, present only 'before the serious work started'.[95] The implication is that like the tea, they would be 'kept by the Professor in its proper place, and not allowed to encroach on the main purpose of the meeting'.[96] None the less, despite their place behind the teapot, the female researchers were to be treated as *ladies*, not maids. At a meeting of the Physical Society on the 'new photography', Rutherford 'discreetly did not go down to the front for tea but paid my devoirs to Mrs Thomson afterwards'. This was because he was wearing 'my Lab. clothes and was unshaven'.[97] The hungry male workers, too engrossed in their experiments to have had a lunch break or considered their appearance, were fed by a gallant troop of ladies whose minds remained at the domestic level of household management. Once serious scientific debate began, the tea ladies would remove themselves from the room to wash the cups and saucers.

This description of female researchers as domestic servants is strongly challenged by Newnham student Catherine Holt, who accurately recorded the proceedings in letters to her mother. 'On Tuesday evening we had the first meeting of the Cavendish Physical Society', she wrote. 'Mrs Thomson, Miss Klaassen, Miss Fawcett and myself are all very keen…Professor Thomson gave us a condensed account of the result of his last eight months' experimental work.'[98] It is quite apparent that Rose Thomson showed considerable interest in the actual scientific proceedings, in contrast to other wives of Fellows who came along: 'Another coach brought his newly acquired wife; I fancy she thought it rather slow and boring…poor little Mrs Wilberforce didn't get much sympathy.'[99] Mrs Wilberforce's ignorance could be tolerated, but not approved, at a social function where she was only

93 Thomson, op. cit. (5), 130–1.

94 *Cambridge Review* (1891), **13**, 31 contains a report of the Cavendish Physical Society's 'first meeting of the present term' which took place on 2 October 1891.

95 G. P. Thomson, op. cit. (3), 91.

96 Wood, op. cit. (3), 26.

97 Eve, op. cit. (53), 27.

98 Holt, op. cit. (23), 32.

99 Holt, op. cit. (23). Comparison can be made with the domestic life of Charles Lyell in the mid-nineteenth century, as observed by Charles Darwin; 'we talked for half an hour, unsophisticated geology, with poor Mrs Lyell sitting by, a monument of patience'. See F. H. Burkhardt *et al.* (eds.), *The Correspondence of Charles Darwin*, 10 vols., Cambridge, 1985–96, ii, 166.

a guest, whilst a knowledge of physics was an expected prerequisite for the Professor's wife.

Though the women might have been interested in the proceedings, there is no evidence to suggest that participation extended to their actually giving presentations. Despite the heterogeneity of the audience, when Professor Ewing described experiments with which he had been assisted by Helen Klaassen, the customary etiquettes of the Royal Society and the Cambridge Philosophical Society were adhered to – the male professor presented the results whilst the female assistant remained seated.[100] Although this was an arena where work done by students could be presented for discussion and critical review by their peers, female voices were barred from the stage.

Thus the women present at the meetings of the Cavendish Physical Society occupied a wide variety of posts; from humble tea lady to respected society hostess, from pretty young wife to educated college student. This multitude of roles highlights the varying positions adopted by women within the laboratory as a whole. This essay has made visible seven different personalities from seven different backgrounds, all of whom managed to negotiate a space for themselves within the Cavendish Laboratory. The women in my narrative did not force their way through solid, unmoving boundaries, but assimilated themselves into a continually changing environment.

SEGREGATION OR INTEGRATION?

Throughout the closing decades of the nineteenth century, women successfully integrated themselves into the culture of Cambridge physics. This can be seen by focusing on collaboration and partnership, an effective alternative to antagonistic narratives that concentrate on battles between the sexes at a superficial level. Indeed, at first glance the Cavendish Laboratory is an unusual candidate for sympathetic writing by feminist scholars. Its namesake, Henry Cavendish, was noted by J. J. Thomson as an ardent 'misogynist' – his female servants were employed on the understanding that they kept out of sight, or face dismissal; all communications with his housekeeper were conducted via letters.[101] When the Cavendish opened in 1874, Maxwell insisted on his 'rule' that all 'students should be male'.[102] The restriction was eventually relaxed in the Long Vacation of 1879, and during these few weeks whilst Maxwell was on holiday in Scotland, the demonstrator, William Garnett, took a class of women through a complete course of electrical measurements.[103] It is easy to view Maxwell's intransigence in a wholly negative light; the authoritarian director who fought against an invasion of his establishment by female intruders. However, we should be wary of removing the Cavendish from a more general context of late Victorian Cambridge. Indeed, Maxwell could almost be regarded as progressive in allowing female footsteps across the threshold at all. Women were not entitled to work in the University Chemical Laboratory until 1909 and they did not join

100 *Cambridge Review* (1891), **13**, 128, account by Professor Ewing of experiments carried out with the assistance of Miss Klaassen. There is no evidence to suggest that women actually presented their own results.

101 Thomson, op. cit. (5), 107.

102 P. A. Kidwell, 'Women astronomers in Britain, 1780–1930', *Isis* (1984), **75**, 536.

103 A. Schuster, 'The Clerk Maxwell period', in J. J. Thomson *et al.*, op. cit. (3), 35–6.

men in physiology practicals until 1914.[104] It is therefore useful to provide a short comparison with the teaching of other sciences within the University, taking both the nature of study and the availability of suitable places to work into account.

One potential objection raised against teaching mixed classes, both in lecture theatres and laboratories, was the indelicacy of teaching certain subjects to the more sensitive sex. On one occasion, when a specimen of the human brain was passed around the lecture audience, the male undergraduates all turned to watch the ladies' reaction.[105] Lecturers in biological sciences complained of embarrassment, of feeling tongue-tied and having to omit certain details from their course material. 'I often have to allude to matter', wrote one University teacher, 'which I find some difficulty in treating adequately before a mixed audience of men and women'.[106] There were, of course, no such indelicacies to contend with in physics. Though a note of caution was raised at the overeagerness of female students to proceed to advanced work without sufficient background knowledge, there was no suggestion of re-tailoring courses to cope with heterogenous classes.[107]

Decisions about integration versus segregation were further complicated by the demands of the increasingly popular Natural Sciences Tripos. Sites for practical work were at a premium throughout the whole University. Women seeking access to laboratories were consequently competing with men for a continually shrinking space and it is hardly surprising that the presence of non-University members in already cramped conditions was resented. In some cases, compromises were reached between the women's colleges and individual University professors to relieve the pressure on facilities. Throughout the 1870s Mr Philip Main rose at 8.30 a.m., three times a week, to instruct women in practical chemistry at his laboratory in St John's College. His early morning classes ceased in 1879 with the building of a chemical laboratory at Newnham 'in the garden at a respectful distance from the original Hall'.[108] Budding female chemists could now attend classes in the afternoon, unchaperoned. A laboratory was also built at Girton in the same year, using a donation of £600 from Lady Stanley of Alderley (Figure 4).[109] In 1884 a biological laboratory for women was constructed on the site of a disused Congregational church, further easing the pressure on the already overcrowded University facilities. The building was primarily funded by educational reformer and later principal of Newnham, Mrs Eleanor Sidgwick, and her sister Miss Alice Balfour in memory of their brother, a promising morphologist.[110] By the end of the 1890s, single-sex space was available in the Balfour Laboratory for women to attend practical sessions in chemistry, elementary physics, morphology, osteology, systematic botany, electricity and physiology.

Where there was no separate provision for women, they were segregated within the same room as the men, the nature of the division heavily dependent on the geography of the teaching area. 'Michael Foster allowed us women to sit up in a gallery overlooking his big

104 Phillips, op. cit. (54), 77–80, for the integration of female students into the University's chemistry and physiology laboratories.

105 Megson and Lindsay, op. cit. (14), 34.

106 'Report of the Degrees for Women Syndicate', *Cambridge University Reporter* (1897), **154**, 600–1.

107 'Report', op. cit. (106).

108 Gardner, op. cit. (17), 37.

109 Megson and Lindsay, op. cit. (14), 34.

110 Fowler, op. cit. (43), 14–15.

Figure 4. Students at work in Girton College laboratory. Note how the light, airy room contrasts with the dingy-looking laboratory in Figure 1. Reproduced by courtesy of the Mistress and Fellows of Girton College, Cambridge.

lecture room', one former student commented, reflecting on her own experiences in the 1870s. The room was 'full of men', though ladies were not allowed to sit amongst them. The situation was different in Frank Balfour's embryology lectures, given 'in a tiny room, where men and women were squeezed together'.[111] Such close physical contact between the sexes was far from ideal, yet there was little consensus on how best to deal with heterogeneous classes. When women occupied the front seats, they were criticized for operating a 'sit first, come first, and see first' policy at the expense of chivalrous undergraduates. When they sat together 'modestly in a row at the back' or in the gallery, demonstrators were forced to waste time by speaking to them separately. If they integrated themselves into the class, their male peers were inhibited from asking too many questions, shy of displaying ignorance in front of ladies. There was no easy solution. Although the practice of having women students sit at the back in physics lectures continued into the 1920s, the Cavendish should not be considered in isolation.[112] Thomson's comments reflect initial worries, common to many, not a lone voice speaking out against the crowd.

111 Letter from an anonymous lady missionary, *British Medical Journal*, 9 October 1920, 572.
112 Kidwell, op. cit. (102), 536.

It should not be forgotten that the position of women students, both undergraduates and research workers, was extremely tenuous. Whilst they may have enjoyed educational advantage similar to male peers, access ultimately lay with the decision of the men. Though favours had been granted, the future was not secure, resting on the say so of professors and lecturers. Female applicants were positively encouraged to work at the biochemistry department by Professor Frederick Hopkins.[113] Conversely, Adam Sedgwick, Reader in animal morphology and afterwards professor of zoology, declared he would 'turn all the women out of his laboratory and not allow them to attend lectures', if they did not stop 'agitating' for degrees.[114] Although the informality of the relationship between women and the University was used in the argument in favour of granting them degrees, formal recognition would not have solved everything. When women were granted full membership of University College London in 1878, after having attended separate classes there for ten years, they were 'solemnly conducted' to empty benches in lectures and practicals, far away from where the nearest men were sat. To avoid unnecessary contact with members of the opposite sex, guides chose alternative entrances and exits. For rooms with only one door, female students were shown to their seats before any of the men had arrived.[115] Degrees handed out to men and women at University College were judged according to an identical academic standard, but in the lecture theatre appropriate behaviour was defined according to sex. The granting of degrees to Cambridge women would have provided them with a formal, academic qualification, but would not have solved issues relating to personal space.

It would be wise to remember that my argument has focused on women research students, not undergraduates. Whilst issues of propriety affected all women, research work was essentially different from undergraduate courses and lectures. The segregation common in undergraduate lectures was not possible to the same extent in a research laboratory where teamwork and partnership were of absolute importance. Indeed, the Cavendish Laboratory was not the only space where student–tutor relationships blossomed into marriage. After the removal of celibacy restrictions in 1882, many women who read natural sciences married into the University.[116] Just as Rose Paget's research into soap films came to an abrupt end on her engagement to Thomson, so Marian Greenwood's work on physiology was ended by marriage to George Bidder.[117] Conversely, Eleanor Wynne Edwards was able to work alongside her husband on projects of geological and botanical interest as Mrs Clement Reid.[118] Given the absence of paid employment for female research workers, marrying into science was one way of ensuring a lifelong intellectual partnership.

113 D. Richter, 'Opportunities for women in science', in *Women Scientists: The Road to Liberation* (ed. D. Richter), London, 1982, 7.

114 J. J. Thomson to Richard Threlfall, 7 August 1887, Cambridge University Library, J. J. Thomson Correspondence, Add. MSS 7654, T19.

115 N. B. Harte and J. North, *The World of University College London: 1828–1990*, London, 1990, 78; N. B. Harte, *The Admission of Women to University College London – A Centenary Lecture*, London, 1979, 18.

116 Macleod and Moseley, op. cit. (4), 332.

117 Obituary of Mrs G. P. Bidder, *Nature* (1932), **132**, 689–90.

118 Obituary of Eleanor Mary Reid, *Proceedings of the Geological Society of London* (1954), **1515**, pp. cxl–cxlii.

CONCLUSION

Researchers who set out to rediscover previously anonymous figures, in order to describe their roles in particular environments, should also consider why these characters were omitted from certain narratives in the first place. Why do we need to go through this long (and often difficult) process of recovery? I do not want to claim that historians have been following a deliberate policy of organized blindfolding, turning the page or looking the other way when they encountered women's names. Instead, I firmly believe that we have been looking for the wrong things in the wrong place. A century of narratives recounting male camaraderie, the eccentric figures of genius guiding enthusiastic manly students, has effectively erased any evidence of the feminine from the history of a world-famous laboratory. In the words of Jeanne Peterson, 'Women's work has often been invisible to historians – partly because of our prejudices about Victorian ladies, partly because their style was not (by and large) the style of men's public action.'[119] Previous histories of physics at Cambridge have been written within a male framework. My essay is about collaboration and integration, not sex war: an environment where women fashioned spaces for themselves instead of fighting tooth and nail to widen a prescribed sphere. Women have to be brought in from the sidelines and placed firmly in the centre of a contextualized history of physics.

The female researchers at the Cavendish Laboratory in late Victorian Cambridge were *not* isolated oddballs, figures of fun for discussion by the male workers.[120] They were family friends, relations, educated women, keen researchers seeking experimental space. The men at the Cavendish did not ridicule their presence but gave directions, suggestions and, occasionally, marriage proposals. Women had an important role to play in the culture of Cambridge University physics, both intellectually and socially. A history of the Cavendish that ignores their presence does not give an accurate representation of its atmosphere. We do not, as has recently been suggested, need to know 'more about the Cavendish men',[121] but more about all of the individuals who made up the Cavendish community.

119 Peterson, op. cit. (10), 161.
120 My evidence clearly contradicts this claim, made by Price, Hughes and Schaffer, op. cit. (35).
121 Kim, op. cit. (3), 226.