The Historical Context of the Gender Gap in Mathematics

Book Section

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June Barrow-Green

1 Introduction

In 1971 the *Association for Women in Mathematics* (AWM), the first organisation for supporting women in mathematics, was established in the United States.[1] There are now many organisations worldwide supporting women in mathematics, and the number continues to grow, with the IMU's Committee for Women in Mathematics (CWM) providing a focal point.[2] Nevertheless, despite the extensive work that has been done since 1971 to address the particular challenges which confront women in mathematics, women still face particular difficulties within their professional careers. Many of these difficulties have a long history stemming from deeply embedded cultural attitudes, some of which have proven difficult to shift. The fact that these attitudes have a long history does not excuse why change has been slow but it does perhaps help to explain it.

In what follows I describe some examples of the challenges faced by women mathematicians during the last two hundred and fifty years, looking first at some individuals from the 18th and 19th centuries, then taking a slightly broader view and considering women within particular national contexts.[3] I make no claim for completeness but through these historical examples I hope to shed light on some of the problems still encountered today.

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[1] For a history of the AWM, see [1].

[2] See https://www.mathunion.org/cwm/organizations/country.

[3] By women mathematicians I mean women who were producing or developing original mathematics. That is not to diminish the contribution of the many women who simply used mathematics, as for example in accounting practices, or who were employed as human computers, but simply to note that they are not the subject of my discussion.

2 The 18th and 19th centuries

The first woman in the modern period to make a substantial contribution to mathematics was the Italian Maria Agnesi (1718–1799) who in 1748 published one of the earliest textbooks on the differential and integral calculus, *Instituzioni Analitiche*, which she originally wrote in order to instruct her younger brothers. Written in the vernacular (which was unusual in the period), the book was accessible to a broad audience and an important contribution to the spread of the calculus in Italy. Two years after the book's publication, she was appointed to the chair of mathematics in Bologna on the recommendation of the Pope, Benedict XIV, but she never took up the position. Agnesi did not even go to Bologna although her name remained on the rolls of the university. Instead she devoted her life to works of charity.[4]

Much has been written on the content and reception of Agnesi's text but I want to draw attention only to some remarks made by the French historian of mathematics, Jean-Etienne Montucla, as they are illustrative of contemporary views about women mathematicians. Montucla, who was writing at the end of the 18th century, was complementary about the book but nevertheless rued the fact that there was no translation of it by one of the French women mathematicians—he didn't say who he had in mind—thereby implying that he believed there to be a difference between the way men and women approach and study mathematics.[5] At the same time, he was also astonished that a woman—or as he put it "a person of a sex that seems so unfit to tread the thorny paths of abstract sciences" [3]—could penetrate so deeply into the calculus, thereby reinforcing the notion of the general unsuitability of women for mathematics.

Agnesi, along with a number of other women in the 18th and early 19th century, such as Émilie du Châtelet (1706–1749), Ada Lovelace (1815–1852) and Mary Somerville (1780–1872), all of whom made lasting and significant contributions to mathematics, were not prevented from doing mathematics, in fact sometimes rather the opposite. For example, Lovelace, today renowned for her remarkable paper which explained the principles of Charles Babbage's analytical engine [4], was encouraged by her mother to study mathematics with Augustus De Morgan.[6] Something these women all had in common was that they came from a social class which gave them the time and the opportunity to discuss mathematics (and natural philosophy) with men on equal terms. Both Somerville and Lovelace attended Babbage's scientific soirées and together they frequently called on him in order to see and to discuss his analytical engine.

That Élisabeth Ferrand (1700–1752), an important influence on Abbé de Condillac and a friend of Alexis Claude Clairaut, chose a page from Voltaire's influential

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[4] For a discussion of Agnesi's life, see Paula Findlen's excellent essay review [2].

[5] There was a French translation by a man, Pierre Thomas d'Antelmy, which appeared in 1775. An English translation by John Colson appeared in 1801. It was a mistranslation by Colson, who confused *a versiera* (the rope that turns a sail) with *l'aversiera* (she-devil), that led to the cubic curve studied by Agnesi being named the 'witch of Agnesi' (an early example perhaps of unconscious bias?).

[6] The teaching was done mostly by correspondence, see [5].

Fig. 1: "Mlle Ferrand méditant sur Newton" by Maurice-Quentin de La Tour

Éléments de la philosophie de Newton (1738)—the book which introduced Newtonian physics to France—as the backdrop to her portrait is indicative of such learning among women in Enlightenment circles (Figure 1).[7] But there may be another reason Ferrand chose Voltaire's book; for Voltaire was not its sole author although his is the only name to appear on the cover and title page. Voltaire's long-time companion, Émilie du Châtelet, played a major role in the book's production and in fact Voltaire did not shy from acknowledging it. Du Châtelet's name appears twice in the introductory matter where Voltaire gives an indication of their collaboration, and she is also depicted in the frontispiece where he has imagined her as a muse floating above him while holding a mirror reflecting Newton's wisdom down onto his hand, thus implicitly admitting her scientific superiority (Figure 2). Although co-authoring was not common practice at the time, by keeping du Châtelet's name from the front cover, Voltaire was nevertheless diminishing the visibility of women as genuine contributors to serious scientific work. Some ten years later du Châtelet completed her own much more ambitious work: *Principes Mathématiques de la Philosophie Naturelle*, a translation from the Latin of Isaac Newton's fiercely difficult *Principia*. But it was much more than a translation: Newton's geometry was rendered into algebra and she provided an extensive commentary including recent research. She completed it while pregnant and died shortly after giving birth. It was not published until 1759, ten years after her death, the publication timed to coincide with the year of the return

[7] For biographical information about Ferrand and a discussion of Maurice-Quentin de La Tour's pastel portrait, see http://www.pastellists.com/Essays/LaTour_Ferrand.pdf.

of Halley's Comet. Today it is still the only complete translation into French of the *Principia*, a testimony to du Châtelet's ability as a mathematician.

Fig. 2: The frontispiece to Voltaire's *Éléments de la Philosophie de Newton*

Although it was acceptable for these women to mix socially in mathematical and scientific circles, they could not hold any sort of academic or institutional position. Somerville was able to make money from the sales of her books—her *Mechanism of the Heavens* (1831), an acclaimed translation and commentary on the celestial mechanics of Pierre-Simon Laplace, became a recommended text for men studying for the Mathematical Tripos at Cambridge[8]—and she could have a paper published

[8] On 14 February 1832, George Peacock, who in 1837 would become the Lowndean Professor of Geometry and Astronomy at Cambridge, wrote to Somerville to say that he considered *The Mechanism of the Heavens* "to be a work of the greatest value and importance," and told her that "Dr Whewell and I have already taken steps to introduce it into our course of studies at Cambridge

by the Royal Society of London,[9] but there was no question of her being admitted as a Fellow of the Society. She could not present her paper to the Society: that had to be done by her husband, William, who was a Fellow. Although that is not to say that the Society did not recognise her scientific excellence. In 1842 HRH The Duke of Sussex (then the most recent past President of the Society) together with other subscribers presented the Society with a marble bust of Somerville to be placed in the Great Hall.

More than a century would elapse before women would be admitted as Fellows of the Royal Society. In 1902 when the physicist Hertha Ayrton (1854–1923) was formally proposed as a candidate for Fellowship for her pioneering work on the electric arc, one reason for not admitting her was the fact that she was married, and married women had no status in law! Although the Royal Society would not admit Ayrton as a Fellow, in 1904 they did allow her to read a paper before the Society—the first woman to do so—and in 1906 they awarded her the Hughes Medal.[10] Thus, the Fellows of the Society were prepared to acknowledge that women could do science, and indeed do it very well, but they were not prepared to accept that women should or could be considered as their scientific equals. It would be another forty years before they would change their minds. The first women to be admitted to the Royal Society were admitted in 1945; the first woman mathematician, Mary Cartwright (1900–1998), was admitted in 1947 [8].

The first woman to be a professional academic mathematician in the modern sense was the Russian Sofia Kovalevskaya (1850–1891). Championed by the Swedish mathematician Gösta Mittag-Leffler, who overcame strong opposition to secure her appointment at the Stockholm Högskola (the forerunner of Stockholm University), she became a full professor in 1889. But despite Kovalevskaya's internationally recognised mathematical talent—she was awarded the Prix Bordin[11] of the Académie des Sciences in Paris in 1888 for her work on the spinning top, with the prize money being increased from 3000 to 5000 francs due to the originality of her results—there was no chance for her to gain a position in one of the mathematical centres of Europe, such as Paris or Berlin [9]. As a foreigner it would have been struggle enough but being a woman made it impossible.

Kovalevskaya herself reported examples of the prejudice that she encountered. In 1869, early in her career, when she was making one of her visits to the London salon of the novelist George Eliot (Mary Anne Evans) she found Eliot, who had

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and I have little doubt that it will immediately become an essential work to those of our students who aspire to the highest places in our examinations." [6]

[9] The paper [7] was Somerville's first publication and although the conclusions in it were later disproved, it established her as a practitioner of science rather than as a student or an onlooker.

[10] Ayrton was the fifth recipient of the Hughes Medal—awarded "in recognition of an original discovery in the physical sciences, particularly electricity or magnetism or their applications"—and the first woman to be awarded it. To date it has been awarded to only one other woman: Michele Dougherty in 2008.

[11] The Prix Bordin, which was second in prestige to the Grands Prix of the Académie, was awarded for scientific subjects as well as mathematics.

an interest in mathematics,[12] very keen to introduce her to the philosopher Herbert Spencer because, as Eliot said openly on the occasion, Spencer denied "the very existence of a woman mathematician" [10]. Then, later, in December 1884, shortly after her appointment as an assistant professor in Stockholm, she would write to Mittag-Leffler [11]:

> I have received from your sister, as a Christmas present, an article by Strindberg, in which he proves as decidedly as two and two make four, what a monstrosity is a woman who is a professor of mathematics, and how unnecessary, injurious, and out of place she is.

These episodes provide a stark reminder of the fact that this was a period when it was widely believed that if women used their brains in order to do mathematics (or science), the effort involved would put a strain on their physical well-being, sapping their strength to such an extent that it would interfere with their ability to have children.

As a gifted female mathematician, Kovalevskaya inevitably attracted attention, but not only because of her mathematics. In 1886, Charles Hammond, the assistant of the English mathematician, James Joseph Sylvester, on seeing a photograph of Kovalevskaya, declared that she was "the first handsome mathematical lady" he had ever seen [12]. (Of course one can wonder how many mathematical ladies he had ever seen!) Clearly beauty was not expected in a female mathematician. After Kovalevskaya's untimely death—she died unexpectedly aged only 41—interest in her appearance intensified. But no longer was there a consensus—for some she was beautiful for others she was not and there was no general agreement. The differing nature of these opinions provides an insight into the disparate views about female mathematicians [13].

Although Kovalevskaya's standing as a mathematician was high at the time of her death, it later suffered setbacks. It is true that some errors were found in her work but nothing that would have harmed her reputation had she been a man. One of the most egregious examples came from the pen of the Italian mathematician Gino Loria, professor of mathematics in Genoa, who in 1903 was putting forward the case for keeping mathematical faculties closed to women [14]:

> As for Sophie Germain and Sonja Kowalevksy, the collaboration they obtained from first-rate mathematicians prevents us from fixing with precision their mathematical role. Nevertheless, what we know allows us to put the finishing touches on a character portrait of any woman mathematician: She is always a child prodigy, who, because of her unusual aptitudes, is admired, encouraged, and strongly aided by her friends and teachers; in childhood she manages to surpass her male fellow-students; in her youth she succeeds only in equalling them; while at the end of her studies, when her comrades of the other sex are progressing, fresh and courageous, she always seeks the support of a teacher, friend or relative; and after a few years, exhausted by the efforts beyond her strength, she finally abandons a work which is bringing her no joy . . .

As Roger Cooke has observed, the most malign element of Loria's judgement is his implication of the necessity of "fixing with precision" the originality in a

[12] Eliot attended geometry lectures in London and frequently incorporated mathematics into her novels, notably *The Mill on the Floss*.

woman's work before admitting it is good [15]. The clear insinuation here being that Weierstrass, Kovalevskaya's teacher, had more to do with Kovalevskaya's work than was apparent, despite the fact that Kovalevskaya was meticulous about citing him. Happily, more recent scholarly work has restored Kovalevskaya to her rightful place in the mathematical pantheon.[13]

Loria's reference to Sophie Germain (1776–1831) prompts some further remarks. Germain, who initially taught herself mathematics from books in her father's library, at the age of eighteen began to read the lesson-books of the professors at the École Polytechnique. As the École did not admit women and she wanted to take her mathematics further, she struck up a correspondence with one of the professors, Joseph-Louis Lagrange. But she used the name of a real male student, fearing, as she later said, "the ridicule attached to a female scientist." She subsequently used the same pseudonym when corresponding with Gauss. However, on discovering her true identity, neither Lagrange nor Gauss responded adversely. Indeed in both cases they were complimentary. She had impressed them with her mathematics and to them that was what mattered. In 1807 Gauss wrote to Germain [17]:

> But when a woman, because of her sex, our customs and prejudices, encounters infinitely more obstacles than men in familiarizing herself with their knotty problems, yet overcomes these fetters and penetrates that which is most hidden, she doubtless has the most noble courage, extraordinary talent, and superior genius.

Notwithstanding the fact that both Lagrange and Gauss were impressed by Germain, and that her work on elasticity gained a prize from the Paris Académie des Sciences,[14] after her death, like Kovalevskya, Germain's star lost much of its lustre. The view that women were not suited to, and therefore not capable of, doing work in higher mathematics, dominated. In Germain's case, this is particularly apparent in connection with her work on Fermat's Last Theorem where her contribution steadily became conflated with that of Adrien-Marie Legendre who credited her with only a small part of a much larger and more substantial piece of work. It was not until the 1990s when David Pengelly and Reinhard Laubenbacher worked on her manuscripts and letters that the true scale of her contribution to the problem was recognised. At the end of their research, Pengelly and Laubenbacher concluded [18]:

> Sophie Germain was a much more impressive number theorist than anyone has ever known.

3 Cambridge University

During the 19th century, Cambridge was the beating heart of British mathematics and the Mathematical Tripos the most prestigious and demanding examination in Britain. It was punishingly hard, both physically and mentally, but the rewards were great. Students who came high up in the list of wranglers (students in the first class)

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[13] See, for example [9], [16].

[14] Germain was the first woman to gain such a prize.

had a passport to the career of their choice, be it the law, medicine, the church or mathematics. It is hard to over-estimate the kudos attached to being senior wrangler, the top mathematics student of the year. Kudos that went far beyond the bounds of Cambridge.

From the second half of the century, women could study mathematics at Cambridge—the women's colleges Girton and Newnham were founded in 1869 and 1872 respectively—but they had to obtain permission to sit the Tripos examination, they could not do so by right, and they could not be awarded a degree (with its privileges and voting rights). For over three-quarters of a century the two colleges were not even officially part of the University (that had to wait until 1948).

In 1880 Charlotte Scott (1858–1931) created a sensation by being judged equal to the 8th wrangler.[15] The newspapers and periodicals were full of her success—she had done better than 93 of the 102 men taking the examination—and the reports are revealing about contemporary views of women mathematicians. *The Spectator* is typical [19]:

> Miss Scott has answered papers set for the mathematical tripos in a manner which would have brought her high on the list of Wranglers, an achievement of no common kind. . . . We hope that the ability which the new system brings out and fosters in women, will not be of a kind to give to those who possess it a character for deficiency in feminine gentleness. We do not believe that it will be so. But even in the rare cases where it is so, the world should remember that there have always been women of the masculine type—only that they have hitherto lacked the means of proving what they could do, though possessing amply the means of proving what they could not be.

Once again mathematics is portrayed as an essentially male pursuit. Nevertheless, Scott's achievement generated a growth in support for female students, and from 1881 women were given the right to take the examinations and to have their results published, albeit separate from the men. But they still could not be awarded degrees.

An even greater sensation was created when, in 1890, Philippa Fawcett (1868–1948) was judged to be above the senior wrangler. Reports were published far and wide, including in the *New York Times* [20]. The satirical magazine *Punch* even produced a cartoon (Figure 3). Fawcett had scored 13% more marks than the highest ranked man, G.T. Bennett, and achieved what many had believed impossible. Nevertheless, when the Tripos list was published, her name (together with that of the other women) still appeared below that of all the men, her position in the examination "above the Senior Wrangler" written in brackets beside it.

After Fawcett's success, the clamour for women to be awarded degrees grew louder but it was still not loud enough. Cambridge did not fully open its doors to women until December 1947. Those who wanted degrees had to go to London or, from 1920, Oxford.

Grace Chisholm (1868–1944), who was placed between the 23rd and 24th wranglers in the Mathematical Tripos of 1892 (and also unofficially achieved a first class in the Final Honours School of Mathematics in Oxford the same year), completed

[15] 1880 was a strong year with Joseph Larmor, future Lucasian professor, being senior wrangler, and J. J. Thomson, future Nobel laureate, being second wrangler.

"SENIORA FAWCETT."
So to be entitled henceforth, as she is Seniorer to the Senior Wrangler.

Fig. 3: Philippa Fawcett celebrated in *Punch*, 21 June 1890

her studies with Felix Klein in Göttingen (see section on Germany below).[16] As a woman, there was nowhere in Britain she could engage in post-graduate research.[17] In 1895 she became not only the first British women to gain a PhD in mathematics but also the first woman anywhere to gain one following a standard period of study and oral examination.[18] Shortly afterwards she married the mathematician William Henry Young who had been her tutor for a term at Girton [22]. Young was content for her to continue with mathematical research but, as he told her, publishing mathematical papers was a man's game [23]:

[16] For a description of Chisholm's experience in Göttingen, see [21].

[17] Men in Britain could engage in post-graduate research but if they wanted a PhD they had to go abroad. The PhD did not come to Britain until after the First World War.

[18] Kovalevskaya, who had studied privately with Weierstrass in Berlin, was awarded a PhD in absentia from Göttingen in 1874 based on the contents of three separate research papers. She took no oral examination.

> The fact is that our papers ought to be published under our joint names, but if this were done neither of us get the benefit of it. No. Mine the laurels now and the knowledge. Yours the knowledge only. . . . Everything under my name now, and later when the loaves and fishes are no more procurable in that way, everything or much under your name.

In the end, the Youngs published 214 papers between them [24]. They were mostly published in William's name with only 18 in Grace's name and 13 co-authored. In 1906 they published their book *The Theory of Sets of Points* together. Although happily such a situation no longer pertains, that is not to say that publishing for women today is without problems. Recent analysis of mathematical publications dating from 1970 has shown that "gender-related publication patterns exist and are one of the factors that lead to an underrepresentation of women in mathematics" [25].

Returning to the situation at Cambridge, aside from Young there were men there who were prepared to provide at least some support for women mathematicians. Charlotte Scott studied algebraic geometry with Arthur Cayley, the Sadleirian Professor, and it was Cayley who recommended her for the position of head of mathematics at the newly opening Bryn Mawr College in the United States, a position which she took up in 1895, no equivalent opportunity being available to her in Britain. Cayley was an active supporter of women's education—for several years he was president of the Council of Newnham College—but realizing that change would be achieved only slowly his work was chiefly behind the scenes. For a long time men like Young and Cayley were part of a small minority in Cambridge—the belief that women were not capable of doing serious mathematics proved extremely hard to shift.

After 1947, women may have been able to get degrees at Cambridge but little changed in other respects, and progress towards gender equality in mathematics has been glacially slow. Mary Cartwright, despite being a Fellow of the Royal Society, was never deemed worthy of a professorship.

The first woman to be elected to a professorship in Cambridge was the applied mathematician Anne Davis in 2002, and as at 2018 a female professor in pure mathematics has yet to be appointed there. Furthermore, there is still a greater gender imbalance among mathematics students at Cambridge than at other universities.[19]

4 Germany

In 1764 Immanuel Kant had pronounced that women who succeeded in mathematics "might as well have a beard" [26]. His point being that if women did succeed in mathematics then they would not be women they would be men! The first concrete sign of progress was in 1874 when Kovalevskaya, having studied privately with Karl Weierstrass in Berlin, was awarded a PhD by the University of Göttingen. But it

[19] For a discussion about the current situation with respect to mathematics students in Cambridge, see the Varsity interview of 2 November 2017 with Julia Gog https://www.varsity.co.uk/news/13945. In 2014 the Faculty of Mathematics at Cambridge achieved an Athena SWAN bronze award. See https://www.maths.cam.ac.uk/womeninmaths/athenaswan.html.

remained an isolated incident until the 1890s when Felix Klein, and subsequently David Hilbert, in Göttingen were allowed to let women to audit lectures. Initially only foreign women were permitted as their special status meant they could be used as a test case.[20] As Klein observed in 1895, "The opinion still prevailing in Germany is that the study of mathematics must be as good as inaccessible to women" [27]. At that time he himself had had six foreign women—American, English (including Grace Chisholm) and Russian—successfully participating in his higher mathematics lectures which prompted him to remark [27]:

> No one would wish to assert, however, that these foreign nations possess some inherent and specific talent that evades us, and thus that, with suitable preparation, our German women should not be able to accomplish the same thing.

Klein encouraged his women students to publish in *Mathematische Annalen*, the journal of which he was the chief editor. The American Mary Winston (1869–1859), whom Klein had originally met in 1893 when she attended both the Mathematics Congress in Chicago and his Evanston Lectures that followed it, was the first, in 1895, with a short note on the hypergeometric function.

The most prolific female author in *Mathematische Annalen* under Klein's editorship was unsurprisingly Emmy Noether (1882–1935), one of the twentieth century's most gifted mathematicians. Noether's life and extraordinary talent for mathematics have been well documented but recently more information has come to light with regard to her unsuccessful application in 1928 for a professorship at Kiel, information which underlines the tremendous difficulty and prejudice she faced in trying to get a position in Germany. When Noether's name was suggested as a possible contender for the professorship by Adolf Fraenkel, a professor at Kiel, Helmut Hasse, then a professor in Halle, was moved to say [28]:

> I am astonished you even seriously consider this possibility. Although I regard her highly in scientific matters, I deem her totally unfit to fill a regular teaching position, even less so in a small university like Kiel. . . . I am of the opinion that one should not make the experiment to appoint a woman as full professor at such a place as Kiel. The experiment should be tried first on a bigger scale where an unsuccessful outcome would not do so much harm.

The applied mathematician Theodor Kaluza was appointed to the position. In 1933 Noether, as a Jew, was dismissed from her "extraordinary" professorship in Göttingen (basically a Privatdozent with an additional small stipend), and emigrated to the United States where she had a temporary position at Bryn Mawr until her premature death in 1935.

5 United States of America

Thanks to the detailed work of Judy Green and Jeanne LaDuke there is now a wealth of information available about the 228 American women mathematicians who earned

[20] In 1891 the American Ruth Gentry was permitted to audit the lectures of Lazarus Fuchs and Ludwig Schlesinger in Berlin for one term before permission was revoked.

PhDs in the United States before 1940 [29].[21] Added to that is the research by Sarah Greenwald, Anne Leggett and Jill Thomley on the AWM which brings the picture in the United States almost up to date [31]. What is striking about the latters' findings is how the percentage of women mathematics PhDs rose fairly steadily decade on decade from the end of the 19th century up to the beginning of the Second World War only then to drop off significantly. As can be seen from the graph which Greenwald et al produced (Figure 4), the 1930s percentage was only really surpassed in the 1990s.

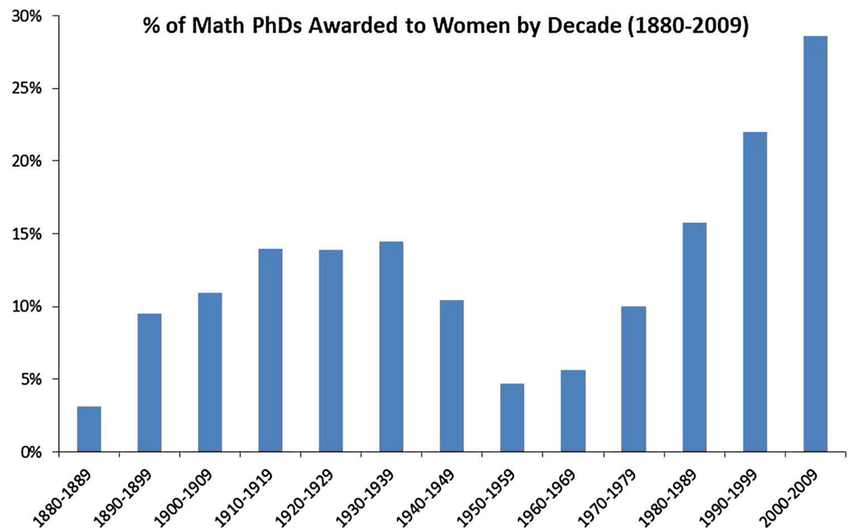

Fig. 4: Percentage of Math PhDs Awarded to Women by Decade (1880–2009)

In the pre-WW2 period, certain institutions in the United States stand out with respect to their support for women mathematicians. Bryn Mawr, the women's college founded in 1895, benefited from having Charlotte Scott at its mathematical helm. Scott supervised seven PhD students and her colleague, and successor as head of mathematics, Anna Johnson Pell Wheeler (1883–1966) supervised six. Both of them, together with Olive Hazlett (1890–1974) who spent a short time as a lecturer at Bryn Mawr, are distinguished for being the only starred women mathematicians in (the inaccurately named) American Men of Science between 1903 and 1943. At the University of Chicago, Leonard E. Dickson supervised 18 women PhDs (27% of his output), and Gilbert A. Bliss supervised 12 women PhDs (23% of his output). Meanwhile at Cornell, Virgil Snyder supervised 14 women PhDs (37%) of his output. In addition, as mentioned above, Klein in Göttingen also supported American women mathematicians.

[21] For additional material by the same authors, see http://www.ams.org/publications/authors/books/postpub/hmath-34.

The lowering of numbers in the immediate post-WW2 period can be largely attributed to the prevailing social conditions which conspired against women mathematicians as it did against women in other fields. It was not until the 1970s, with the advent of organisations supporting women mathematicians, that significant improvements were made.

6 The growth of institutional support for women in mathematics

In general, national mathematical societies have been welcoming to women members. However, the same cannot be said of their governing bodies. The American Mathematical Society was exceptional in appointing Charlotte Scott as a Vice-President in 1906, but it took the Society until 1983 before it appointed its first woman president, Julia Robinson. The first Society to appoint a woman president was the Société Mathématique de France when they elected Marie-Louise Dubreil-Jacotin in 1952. Even in recent times, the number of women in senior roles within societies has not accurately reflected the contribution of women to mathematics as a whole.

After the formation of the AWM in 1971, a number of other organisations supporting women in mathematics were established in North America and Europe: The Joint Committee on Women in the Mathematical Sciences (1971), European Women in Mathematics (1986), The Women in Mathematics Committee of the European Mathematical Society (1991), Femmes et Mathématiques (1987), The Canadian Society Committee for Women in Mathematics (1992) and the London Mathematical Society Women in Mathematics Committee (1999).

At the First European Congress of Mathematics in 1992, there was a Round Table on Women in Mathematics organised by the Women in Mathematics committee (WiM) of the European Mathematical Society. The aim of the Round Table was to look at the proportion of women involved in mathematics in various countries. Its report contains a wealth of information and data providing a detailed picture of the situation [32]. Among the examples demonstrating the ingrained bias that still existed at that time was one provided by Eva Bayer-Fluckiger concerning the pre-printed postcards supplied by mathematical departments to be used for reprint requests. These cards contained a text that ran roughly as follows:

> Dear Sir,
> Please send me a reprint of your article . . . that appeared in. . . .
> Many thanks in advance.
> Yours sincerely.

Bayer-Fluckiger had recently received such a card that had the text in three languages: “Lieber Herr Professor; Monsieur le Professor; Dear Sir”. The idea that the author of a mathematical article could be a woman simply wasn’t entertained. In commenting on the “deplorable” German situation in comparison with other European countries, Christine Bessenrodt, in her talk at the Round Table, noted that although about one third of students in mathematics were women, “only 9% of dissertations and 7% of habilitations are written by women, and only 2% of the professors in mathematics are female." And she found it a very depressing task "investigating the status quo and compiling a list of obstacles that women in mathematics have to face in Germany." So much so that she found "it surprising that there are women mathematicians at all in [Germany]". Such examples paint a vivid picture of the poor situation for women mathematicians in Europe at that time as well as highlighting the extent of the gender gap.

The WiM committee, helped by funding from the UK Royal Society Athena Awards, gathered data about women mathematicians across Europe in 1993 and again in 2005 (Figure 5).[22] Although the data shows a substantial increase in the percentage of women mathematicians during the intervening 12 years, it also reveals a significant difference between north and south, highlighting the countries in which the greatest efforts need to be made.

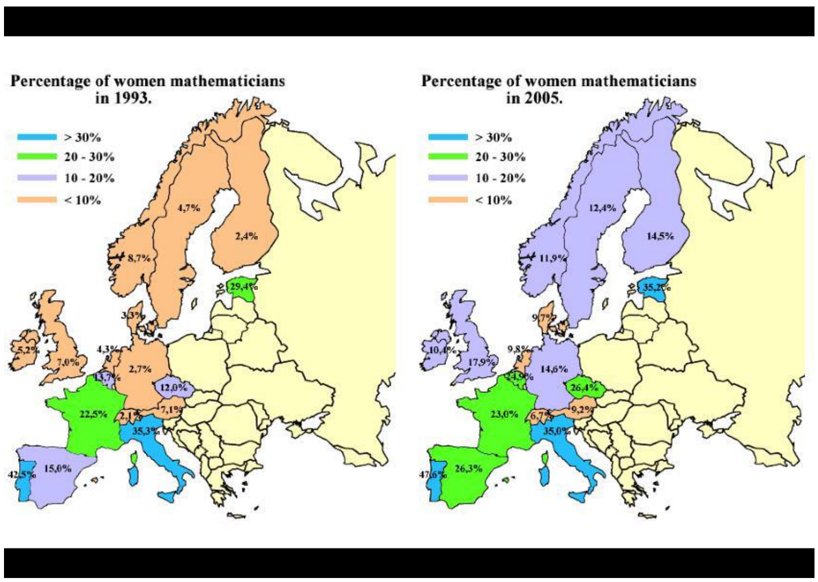

Fig. 5: Percentage of women mathematicians in Europe in 1993 and 2005

Since 2000 the number of organisations set up to support women in mathematics has grown worldwide. In addition to those organisations named above, there are now organisations in countries across the globe, as well as umbrella organisations for African Women in Mathematics and Central Asian Women in Mathematics.[23] In 2015, with a remit to promote international contacts among all of these organ-

[22] For details of the data, see C. Hobbs, E. Koomen 'Statistics on Women in Mathematics' (2006), https://womenandmath.files.wordpress.com/2007/09/statisticswomen.pdf.

[23] For information about the different national organisations, see https://www.mathunion.org/cwm/organizations/country.

isations, the IMU Committee for Women in Mathematics (CWM) was founded. The CWM website provides information about all the national organisations and much more besides, including links to articles about the recent history of women in mathematics.[24]

7 The last word goes to Ingrid Daubechies

In 2010, Ingrid Daubechies was elected as the first woman president of the International Mathematical Union, her term of office running from 2011–2014. On 29 July 2014, just prior to the ICM in Seoul, Daubechies was interviewed for The World Academy of Sciences. Among the questions she was asked was:[25]

> *There's a common assumption that women are less good than men at mathematics. What could be the reason for this, assuming it is true?*

Here is Daubechies' response (her emphasis):

> I disagree with this view—*completely*. There is a highly variable percentage of women in academia and in departments of mathematics across Europe. Differences are so enormous that it becomes obvious that it has something to do with cultural habits, which differ from one nation to another, and not with intelligence. I have a very cynical colleague who says that the number of women mathematicians who are in academia is inversely proportional to some average of the amount of money and prestige that the job can grant: If there is little money and no prestige, there you'll find more women. I agree: These aspects seem to play a much larger role than being smart.

Daubechies draws attention to an important issue. She points out, and the historical examples support it, that even in a highly theoretical field such as mathematics, with often flexible working environments and relatively clear criteria for quality of work, social and political conditions impede the equality of women. But this very fact gives cause for hope too: these are conditions that can be changed and are being so, albeit not as fast as they might be.

We are not condemned to the repetition and perpetuation of past mistakes.

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