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THE GENDER GAP IN MATHEMATICAL AND NATURAL SCIENCES FROM A HISTORICAL PERSPECTIVE

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Abstract

The panel organised by the Committee for Women in Mathematics (CWM) of the International Mathematical Union (IMU) took place at the International Congress of Mathematicians (ICM) on August 2nd, 2018. It was attended by about 190 people, with a reasonable gender balance (1/4 men, 3/4 women). The panel was moderated by Caroline Series, President of the London Mathematical Society and Vice-Chair of CWM. Presentations were made by Marie-Françoise Roy, Chair of CWM, June Barrow-Green, Chair of the International Commission on the History of Mathematics, and Silvina Ponce Dawson, Vice-President at Large and Gender Champion of the International Union of Pure and Applied Physics (IUPAP). The presentations were followed by general discussion. Marie-Françoise briefly outlined the history and activities of CWM and described the ongoing "Gender Gap in Science" project which is being carried out under the leadership of IMU and the International Union of Pure and Applied Chemistry (IUPAC), with the participation of IUPAP and many other scientific unions. June gave some insights into the historical context of the gender gap in mathematics, while Silvina gave an overview of activities undertaken by the IUPAP Working Group on Women in Physics to evaluate and improve the situation of female physicists.

What follows are the authors' accounts of their presentations together with some notes on the subsequent discussion.

1 The International Mathematical Union (IMU) Committee for Women in Mathematics (CWM)

1.1 Creation and organization of CWM. CWM was created by the IMU Executive Committee (EC) in March 2015 with the following terms of reference:

(1) To promote international contacts between national and regional organizations for women in mathematical sciences;

(2) To maintain up-to-date content on the Women in Mathematics part of the IMU website and, with appropriate assistance from the IMU, to ensure its technical development;

(3) To consider how best to facilitate electronic communications among the community of women mathematicians internationally;

(4) To work with groups, committees and commissions of IMU on topics pertaining to women mathematicians and their representation;

(5) To publicize, and where needed to suggest, working practices that ensure equal opportunities for women mathematicians in universities and research institutions, for example appropriate funding arrangements, family friendly policies and facilities;

(6) To report annually to the IMU Executive Committee and to propose actions that would foster equal treatment of women in the mathematical community and lead to an increase in the representation of women in mathematics at all levels.

The CWM has a chair and a vice-chair, and 6 to 8 members at large, who are appointed for four years in accordance with the EC terms, and whose country of residence should be distributed internationally, reflecting the global character of CWM.

The list of committee members in the period 2015–2018 was as follows: Marie-Françoise Roy, France (Chair, in charge of electronic communication); Caroline Series, UK, (Vice Chair, in charge of the CWM website); Carolina Araujo, Brazil; Bill Barton, New Zealand; Ari Laptev, UK and Sweden; Kristin Lauter, USA; Sunsook Noh, S. Korea; Marie-Françoise Ouedraogo, Burkina Faso; Sujatha Ramdorai, Canada; Betül Tanbay, Turkey. CWM also had two associate members, Neela Nataraj (India - Coopted for coordinating grant reports) and Petra Bonfert-Taylor (USA - Coopted for website). The liaison with EC was made by John Toland, UK.

The impetus for creating CWM followed the formation of a group of female mathematicians led by Ingrid Daubechies whose aim was to collect and organise information for a new Women in Maths section of the IMU website. The CWM website was launched at the ICM in Seoul 2014. When CWM started, the website was updated accordingly; publicity for the new committee was done at the same time. Items (events, new women in maths organisations, newsworthy items, resources etc.) are added every week. The site lists an impressive number of events related to women mathematicians in 2015–18 in all parts of the world. In addition, 36 countries are listed with some form of organisation, activities or contacts. The site has a unique and important function as the only platform for coordinating so much diverse activity worldwide.

CWM has in addition established a network of (currently) 120 *CWM Ambassadors*, each of whom is responsible for disseminating relevant information such as CWM funding calls within her geographical or mathematical area and of keeping CWM informed about relevant activities or initiatives.

1.2   CWM call for proposals.   At its first meeting in Cortona, Italy in September 2015, CWM decided to use most of its budget to support the formation of networks of female mathematicians on a regional basis in developing or emerging countries. Annual calls were organized in 2016, 2017 and 2018. A total of 155 applications were received and 31 were supported, most of them in developing or emerging countries from Africa (Ethiopia, Morocco, Kenya, Nigeria, Senegal, South Africa, Tunisia), Asia (India, Indonesia, Iran, Japan, Kazakhstan, Nepal, Uzbekistan, Vietnam), Latin America (Brazil,
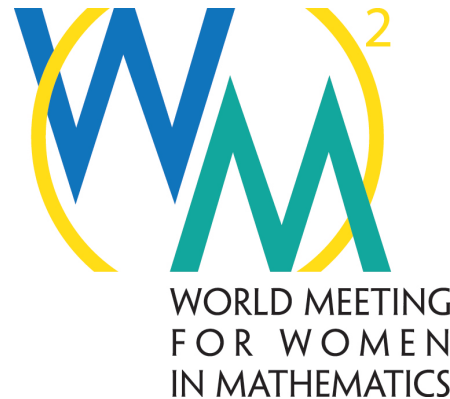
Figure 1: World Meeting for Women in Mathematics (WM)^2

Chile, Colombia, El Salvador, Mexico, Uruguay) as well as Austria, Canada, Italy and Macedonia. Also, almost all grants in developed countries support the participation of women from developing countries. Around 2500 people, most of them women, participated in the various events.

CWM initiated the World Meeting for Women in Mathematics (WM)^2 project. The first (WM)^2 in Rio, with main organizer Carolina Araujo, had a strong Latin American focus and took place immediately prior to the ICM, on Tuesday July 31st, 2018. A professional designer created a logo and poster, the domain name worldwomeninmaths.org was reserved and a website company designed the website. (WM)^2 was approved as a satellite meeting of the ICM on 15 February 2016. The scientific committee chaired by Georgia Benkart (University of Wisconsin-Madison) has selected a key-note lecturer (Monique Laurent), three invited lecturers (Alicia Dickenstein, Salome Martinez, Maria Eulalia Vares) and a public lecturer (Maria Esteban). The program also included group discussion, presentation of 100 posters (both mathematical and on women in mathematics), and a tribute to Maryam Mirzakhani. The 293 Female OpenArms grantees were offered free registration for (WM)^2. Finally more than 350 people attended, more of one third of them from the OpenArms programme.

1.3   Women mathematicians in film.   A short film for International Women's Day 2018, *Faces of Women in Mathematics*, was suggested by Eugenie Hunsicker, Chair of the London Mathematical Society Women in Maths Committee, and Irina Linke, a filmmaker. It consists of an edited sequence of film clips of women saying into the camera "I am (name) from (country), and I am a mathematician!" in the language of their choice. The 146 clips, sent in as a result of a message circulated to CWM ambassadors, featured 243 women mathematicians from 36 different countries speaking in 31 different languages. CWM used a small part of its budget for editing the clips and the film has been greatly appreciated by all who have seen it.

Journeys of Women in Mathematics

With a recommendation from Ingrid Daubechies, CWM proposed creating a short film *Journeys of Women in Mathematics* to the Simons Foundation. Micro-Documentaries has been selected to film and edit the film. The focus is on the diversity of women mathematicians worldwide. The first version, shown at $(WM)^2$, presents three women active in organizing regional networks: Carolina Araujo (Rio, Brazil) the $(WM)^2$ main organizer and also an ICM lecturer; Neela Nataraj (Mumbai India), an active member of Indian Women in Mathematics and Aminatou Pecha (Yaounde, Cameroon), the founding chair of the Cameroon Women in Mathematics Association. Micro-Documentaries met them in their home countries. The second augmented version will highlight six women from Latin America, including the three invited lecturers at $(WM)^2$.

1.4   Maryam Mirzakhani Memorial exhibition. Made for $(WM)^2$ and remaining posted throughout the entire ICM2018, the exhibition consisted of 18 posters inspired by Maryam Mirzakhani's achievements and her premature death, two specially printed books containing all her mathematical papers, one book with articles about her, and a book of condolences. The Maryam Mirzakhani Memorial exhibition will be permanently hosted by Stanford University and will also be made available at scientific events by agreement of the organizers with CWM.

1.5   CWM flier and posters. Using a professional designer, CWM created a flyer and poster, which was distributed through CWM Ambassadors and organizers of CWM funded events. A CWM roll-up for use in displays has been designed in the same style. Three posters (one for Africa, one for Asia, one for Latin-America) reporting on CWM funded activities since ICM Seoul have being designed for display at $(WM)^2$ and ICM Rio.

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1.6   **Interdisciplinary project Gender Gap in Science.**   CWM joined forces with the International Union of Pure and Applied Physics (IUPAP) and the International Union of Pure and Applied Chemistry (IUPAC) and submitted a project entitled *A Global Approach to the Gender Gap in Mathematical, Computing and Natural Sciences: How to Measure It, How to Reduce It?* to the International Council for Science (ICSU) in 2016. Lead by the IMU with IUPAC as co-lead applicant, the application was approved on 7 February 2017 (with a budget from ICSU of €100 000 per year in 2017, 2018 and 2019). There are 9 other partners in the project: International Union of Pure and Applied Physics (IUPAP), International Astronomical Union (IAU), International Council for Industrial and Applied Mathematics (ICIAM), International Union of Biological Sciences (IUBS), International Union of History and Philosophy of Science and Technology (IUHPST), United Nations Educational, Scientific and Cultural Organization (UNESCO), Gender in Science, Innovation, Technology and Engineering (GenderInSITE), Organization of Women in Science for the Developing World (OWSD), Association for Computing Machinery (ACM).

Barriers to achievement by women in mathematical, computing and natural sciences persist, especially in developing countries. The aim of the project is to produce sound data to support the choices of interventions that ICSU and member unions can feasibly undertake. It will provide evidence for informed decisions, including trends – since the situation for women continues to change around the world, with some negative developments – and will provide easy access to materials proven to be useful in encouraging girls and young women to study and work in these fields. It will do this through three tasks: (Task 1) a global survey planned to reach 45,000 respondents in more than 130 countries using at least 8 languages; (Task 2) a study on publication patterns which will analyze the effects of gender and location on scientists publication behavior using data on more than 500,000 scientists since 1970. Finally, it is impossible to ignore that there are many initiatives around the world that aim to enhance the participation of girls and
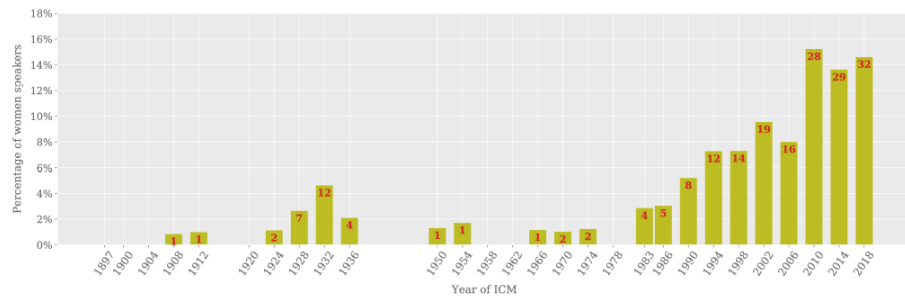
Figure 2: Percentage of women speakers at ICM (as well as numbers)

women in science and mathematics. Which ones work? What is the evidence for effectiveness? Can effective practices developed in one place be used in other contexts? These are some of the questions that will structure an online database of good practices (Task 3).

The project's part focussing on publication patterns is based on methods and research questions from a recent study in Mathematics Mihaljević-Brandt, Santamaría, and Tullney [2016]. Based on four decades of data from Zentralblatt Math, the authors showed a systemic gender imbalance in the publication distribution of mathematicians: women mathematicians tripled their number since 1970, but they publish less than men at the beginning of their careers and leave academia at a higher rate; high-ranked journals publish fewer articles by women, some showing less than 5% authorships by women with no change over time; women publish fewer single authored papers, although their coauthor networks are similar in size to those of men.

As part of the project, the Gender Gap inside among ICM's invited speakers has also been studied. As presented at (WM)² in a poster by Helena Mihaljević and Marie-Françoise Roy the number of women sums up to 201, less than 5% in total. Of all lectures delivered by women in the history of ICM, 80% took place after 1990. In the recent three ICMs the share of women lecturers has grown to approximately 14%. The poster provided glimpses into individual career paths of some of the invited women speakers, and documents the interesting and nonlinear development of women's presence within this community.

2   The Historical Context of the Gender Gap in Mathematics

2.1   Introduction. In 1971 the *Association for Women in Mathematics* (AWM), the first organisation for supporting women in mathematics, was established in the United States Blum [1991]. 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 focus point, for more details see Math Union web site. 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. What follows
is a glimpse at some of the challenges that women mathematicians have had to face
during the last two hundred and fifty years.

2.2   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 calculus. Two years later 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, choosing to devote her life to works
of charity. In fact Agnesi never even went to Bologna although her name remained on
the rolls of the university. With reference to her work and the more general question of
how women mathematicians were perceived in the 18th century, an interesting remark
was made by the French historian of mathematics, Jean-Étienne Montucla (1725–1799),
who said that he wished that the *Instituzioni Analitiche* had been translated into French
by a French female mathematician, thus implying he believed there was something
intrinsically feminine about the text.

Agnesi, along with 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 pre-
vented from doing mathematics, in fact sometimes rather the opposite. For example,
Ada Lovelace was encouraged by her mother to study mathematics with Augustus De
Morgan Hollings, Martin, and Rice [2017]. One thing these women all had in common
was that they came from a social class which allowed them to attend social functions
where they could discuss mathematics and natural philosophy with men on equal terms.
Both Mary Somerville and Ada Lovelace attended the scientific soirées of Charles Bab-
bage (1791–1871) and together they frequently called on him in order to see and to
discuss his analytical engine. That Élisabeth Ferrand (1700–1752), an important influ-
ence on Abbé de Condillac and a friend of Alexis Claude Clairaut, chose a page from
Voltaire's influential *Eleménts de la philosophie de Newton* (1738)—the book which
introduced Newtonian physics to France—as the backdrop to her portrait is indicative
of the acceptability of such learning among women in Enlightenment circles (Figure 3).
For biographical information about Ferrand and a discussion of Maurice-Quentin de La
Tour's pastel portrait, see Jeffares [2016].

However, although women could mix socially in mathematical and scientific circles,
they could not hold an official position. Mary Somerville could make money from the
sales of her books—her *Mechanism of the Heavens*, Somerville [1831], an acclaimed
translation and commentary on the celestial mechanics of Pierre-Simon Laplace (1749–
1827), Laplace [1798], became a recommended text for men studying for the Mathe-
matical Tripos at Cambridge—and she could have a paper published by the Royal So-
ciety but there was no question of her being admitted as a Fellow of the Royal Society,
Mason [1992]. The first women mathematician to be admitted was Mary Cartwright
(1900–1998) in 1947.

Figure 3: "Mlle Ferrand méditant sur Newton" by Maurice-Quentin de La Tour

The first woman to be a professional academic mathematician 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, she became a full professor in 1889. But despite Kovalevskaya's internation-
ally recognised mathematical talent—she was awarded the Prix Bordin of the French
Académie des Sciences for her work on the spinning top—there was no chance for
her to gain a position in one of the mathematical centres of Europe, such as Paris or
Berlin.Koblitz [1983, pp. 215–217], Kovalevskaya herself reported an example of the
prejudice that existed against women mathematicians during the period. 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 an interest in mathematics,
very keen to introduce her to the philosopher Herbert Spencer because, as Eliot said,
Spencer denied "the very existence of a woman mathematician." Kovalevsakya [1978,
p. 359].

As a gifted female mathematician, Kovalevskaya inevitably attracted attention, but
not only because of her mathematics. James Joseph Sylvester's assistant declared that
she was "the first handsome mathematical lady" he had ever seen. (Of course one can
wonder how many mathematical ladies he had ever seen!) Beauty it seems was not ex-
pected in a female mathematician. After Kovalevskaya's death – she died unexpectedly
aged only 41 – her fame escalated and 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. Opinions about her looks still abound and, as has been observed, the differing nature of these opinions, provide an insight into the changing views about female mathematicians Kaufholz-Soldat [2017].

2.3   Cambridge University.   During the 19th century, Cambridge was the beating heart of British mathematics and the Mathematical Tripos the most prestigious examination in Britain. It is hard to over-estimate the kudos attached to being senior wrangler, the top student of the year. Kudos that went far beyond the bounds of Cambridge. Although from 1869/1872 women could study mathematics at Girton/Newnham, women did not have the right to sit the examination—permission had to be granted— and they could not obtain a degree. Indeed the colleges were not 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.[1] 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 provide an interesting insight into prevailing attitudes. *The Spectator* was typical:

> "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." *The Spectator* [1880, p.163].

Scott's achievement generated a growth in support for women students with the result that from 1881 they were given the right to take the examinations and their results were published, albeit separately from the men. But still they 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. She had achieved what many had believed impossible. Nevertheless, when the Tripos list was published, her name still appeared below that of all the men. After Fawcett's success, the clamor for women to be awarded degrees grew louder but still not loud enough. Cambridge did not fully open its doors to women until 1947. Those who wanted degrees had to go to London or, from 1920, Oxford. Those who wanted to study for higher degrees had to go abroad – the PhD did not come to Britain until after the First World War.

Grace Chisholm (1868–1944), who sat the Tripos in 1892, completed her studies with Felix Klein in Göttingen (see below) and in 1895 became the first British women

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[1]1880 was a strong year with Joseph Larmor, future Lucasian professor, being senior wrangler, and J. J. Thomson, future Nobel laureate, being second wrangler.

to gain a PhD in mathematics (and the first woman in Germany to gain a conventional PhD). Shortly afterwards she married the mathematician W. H. Young. Young was content for her to continue with mathematical research but, as he told her rather directly in 1902, publishing mathematical papers was a man's game:

> "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."Grattan-Guinness [1972, p. 141].

Although such a shocking situation no longer pertains, recent analysis has shown that "a systemic gender imbalance" in the publication distribution of mathematicians still exists Mihaljević-Brandt, Santamaría, and Tullney [2016].

Young was not alone as a man supporting 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 founded Bryn Mawr College in the United States, a position which she took up in 1895, no equivalent opening being available to her in Britain. But for a long time men like Young and Cayley were in the minority—the belief that women were not capable of doing serious mathematics proved extremely hard to shift in Cambridge.

After 1947, women could be awarded degrees at Cambridge but further progress towards gender equality in mathematics was and continues to be glacially slow. Mary Cartwright (1900–1998), who in 1947 was the first female mathematician to be elected a Fellow of the Royal Society, and who in the following year became Mistress of Girton, was not deemed worthy of a professorship. The first woman professor of mathematics in Cambridge, the applied mathematician Anne Davis, was appointed only in 2002. As at 2018 no female professor in pure mathematics has ever been appointed at Cambridge. Furthermore, the gender imbalance in mathematics students remains considerably greater than elsewhere.[2] In 2014 the Faculty of Mathematics at Cambridge achieved an Athena SWAN bronze award.

2.4   Germany. In 1764 Immanuel Kant had pronounced that women who succeeded in mathematics "might as well have a beard."Kant and Goldthwait [2004, p. 79]. 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 in Göttingen in absentia. But it remained an isolated incident until the 1890s when Felix Klein, and subsequently David Hilbert, in Göttingen began to allow women to audit lectures.[3] But as Klein observed in 1895, the general opinion in Germany was that the study of

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[2]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.

[3]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.

mathematics should be as good as inaccessible to women. At that time he himself had had six women successfully participating in his higher mathematics lectures but all were foreigners (American, English and Russian) which prompted him to remark:

> "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." Tobies [n.d.].

Klein also 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 Emmy Noether (1882–1935). Noether's life and extraordinary talent for mathematics have been well documented but recently more information has come to light with regard to her application in 1928 for a professorship at Kiel, information which underlines the tremendous difficulty she faced in trying to get a position in Germany Siegmund-Schultze [2018].

2.5   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 PhDs before 1940 Green and LaDuke [2009] including supplement material by the same authors. Added to that is the very informative article by Sarah Greenwald, Anne Leggett and Jill Thomley on the AWM which brings the picture in the United States up to date Greenwald, Leggett, and Thomley [2015]. What is striking about their 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 in the article by Greenwald et al. (Figure 4), the 1930s percentage was only really surpassed in the 1990s Greenwald, Leggett, and Thomley [ibid., p. 13]

In the pre-WW2 period, certain institutions stand out. 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* from 1903 to 1943. In 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 in Cornell Virgil Snyder supervised 14 women PhDs (37%) of his output. In addition, as already noted, Klein in Göttingen also supported American women mathematicians.

In the aftermath of WW2, the social conditions conspired against women mathematicians as it did against women in other fields. It was not until the 1970s, with the
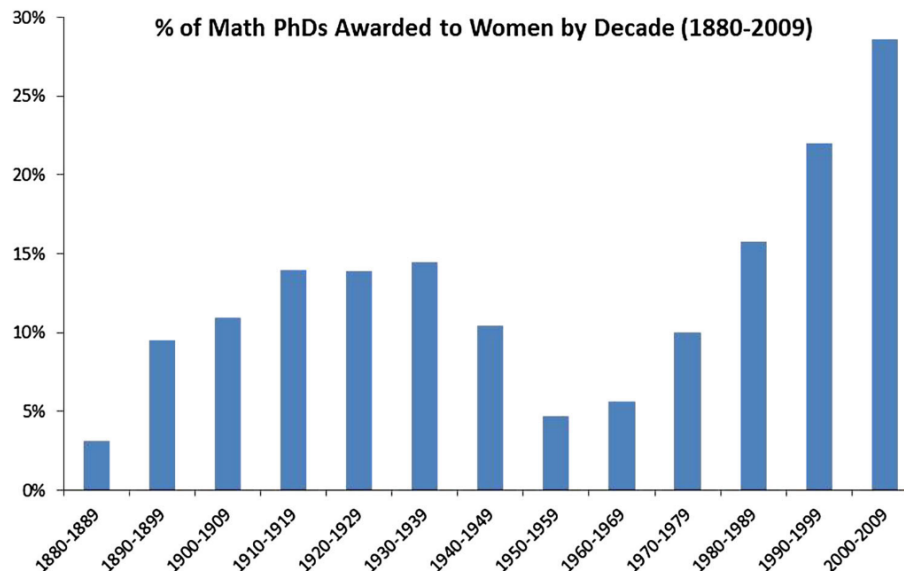
Figure 4

advent of organisations supporting women mathematicians, that significant improve-
ments could be seen.

2.6   The growth of institutional support for women in mathematics.   In general,
national mathematical societies have been welcoming to women members. However,
the same is not true of their governing bodies. The American Mathematical Society
was exceptional in appointing Charlotte Scott as a Vice-President in 1906, although it
took the Society until 1983 before it appointed its first woman president, Julia Robin-
son. 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 support-
ing women in mathematics were established in North America and Europe: *The Joint
Committee on Women in the Mathematical Sciences* (1971), *European Women in Math-
ematics* (1986), *Femmes et Mathématiques* (1987), *The Women in Mathematics Com-
mittee of the European Mathematical Society* (1991), 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* (EMS). The aim of the Round Table was to look
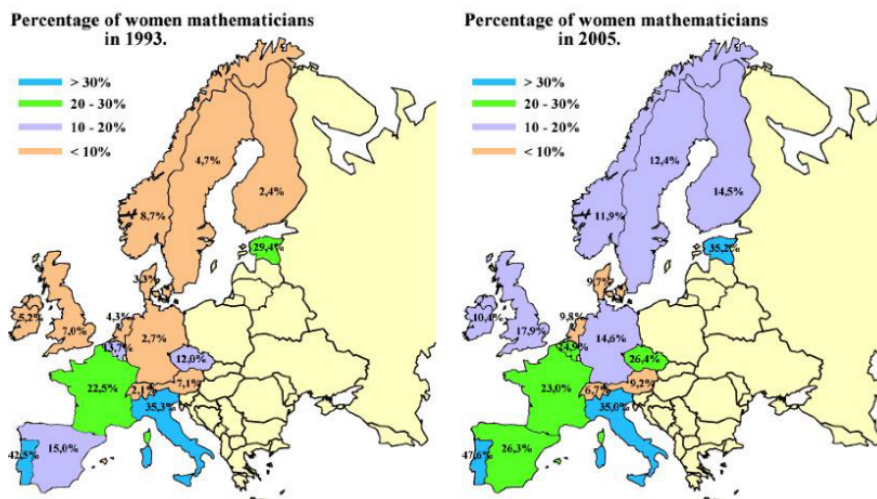at the proportion of women involved in mathematics in various countries. Its report

Figure 5

contains a wealth of information and data providing a detailed picture of the situation, Bayer-Fluckiger [1994].

The WiM committee, with the help of the EMC, gathered data about women mathematicians across Europe in 1993 and in 2005 (Figure 5). Although the data shows a substantial increase in the percentage of women mathematicians during the intervening period, it also reveals a significant difference between north and south, highlighting where the greatest efforts need to be made.

Since 2000 the number of organisations set up to support women in mathematics has grown worldwide. There are now organisations in Australia, Cameroon, Chile, China, India, Israel, Iran, Kenya, Korea, Pakistan, Peru, Poland, Russia, Senegal, Spain, Tunisia, and Turkey, as well as umbrella organisations for African Women in Mathematics and Central Asian Women in Mathematics. Information about all of these organisations, and much more, can be found on the website of the IMU Committee for Women in Mathematics.

3   Gender-related policies of the International Union of Pure and Applied Physics

3.1   The International Union of Pure and Applied Physics.   The International Union of Pure and Applied Physics (IUPAP) was created in 1922 to assist in the worldwide development of physics, to foster international cooperation in physics, and to help in the application of physics toward solving problems of concern to humanity. Membership in the IUPAP is through country representation. Currently 68 countries are represented in the Union. The IUPAP is governed by the General Assembly that meets once very

three years. Its main executive body is the Executive Council which, among other things, oversees the activities of 19 specialized Commissions. There are also Working Groups that are created with a finite time duration to address specific problems.

3.2   The Working Group on Women in Physics. In 1999 the IUPAP General Assembly decided to create the Working Group on Women in Physics with the mandate of evaluating the situation of women physicists worldwide and suggesting ways to improve it. Since then, the Working Group has engaged in very intense activity that helped bring the issue upfront in many countries and made the physics community aware that there was a problem that called for specific actions. It also prompted the formation of Working Groups in all continents leading to the creation of a network of women physicists that spans more countries than IUPAP members.

The first activities of the Working Group included: subcontracting the Statistical Research Group of the American Institute of Physics (AIP) to perform a survey to analyze the situation of women physicists, encouraging the creation of Working Groups in all IUPAP country members and organizing the International Conference on Women in Physics (ICWIP).

3.3   International Conference on Women in Physics (ICWIP). The first ICWIP, which took place in Paris in 2002, was attended by about 300 people from more than 65 countries. This conference established the main guidelines that were applied to all following ICWIPs. Participation is by country. This led to the formation of country Working Groups that are in charge of collecting local data on the situation of women physicists and of taking the necessary steps to induce change in their own place. To ensure a fair distribution of ICWIP participants from more or less developed countries, a limit has been set on the number of country team members that can attend a conference. Countries wanting to surpass this limit have to fund the attendance of as many participants from countries in financial need as the number of members they want to include beyond the limit. ICWIP participation is not limited to women. On the contrary, the Working Group recommends that a minimal country representation should include one senior female physicist, one female graduate student and one man. Since 2002, ICWIPs have been organized with the same frequency as the IUPAP General Assembly (once every three years) rotating throughout the world (Rio de Janeiro, Brazil; Seoul, South Korea; Stellenbosch, South Africa; Waterloo, Canada; Birmingham, UK). ICWIPs have five main types of activities: plenary talks given by recognized female physicists about their research with some recollection of their personal lives; parallel break-out sessions devoted to discuss issues directly related to gender equity in physics; poster sessions where country teams report on the situation of women physicists in their own country, a scientific poster session whose aim is to facilitate the establishment of research networks between participants and a final conference assembly. The outcome of the break-out sessions is to draft a set of recommendations that are presented, modified and voted on in the final assembly. All ICWIPs also organize outreach activities

for school children and the general public destined to remove stereotypes and change the perception about women physicists.

3.4   Travel program. Another important activity of the Working Group is to award Travel Grants for young female physicists from developing countries to attend conferences or schools outside their home institutions. Between 20 and 40 awards of this type are given out in "non-ICWIP" years. Otherwise, the grants are used to fund attendance to the ICWIP. As a way to create awareness of the situation of women physicists, the working group has also decided to celebrate the International Women in Physics Day on February 11th, the same date as the International Day of Women and Girls in Science as established by the United Nations. Finally, the Group is currently finalizing the elaboration of the "Waterloo Charter", a declaration of principles on inclusivity in physics with a set of guidelines that will be presented for approval of the Executive Council. This Charter is based on the rubrics of the Baltimore Charter and the Pasadena Recommendations that were formulated by the American Astronomical Society and is shaped and guided by the principles dictated by the Project Juno of the Institute of Physics in the UK.

3.5   Survey of Physicists. After the first two surveys of physicists, each of which were responded to by about 2000 women, the Working Group subcontracted the AIP Research Center to carry on a global survey of physicists that was available in 8 languages, remained open for one year in 2009–2010 and was responded by 15,000 people of all genders. This Global Survey showed the relevance of early educational experiences for choosing physics, that the personal lives of women physicists were more affected by their careers than those of men, that male physicists were more likely than women to have spouses who did not work and took care of home, and that women had their children earlier than men during their careers, something that was directly implicated in their slower progression. But the difficulties in making personal lives and careers compatible were not the only reason behind this (on average) slower progression. The survey also showed that women had a harder time than men finding certain professional opportunities such as international visits, invitations to speak, supervisory experiences, serving on influential committees, serving as journal editors and advising graduate students. The IUPAP is now collaborating with several other scientific unions in the Gender Gap in Science project which, with the leadership of IMU, has among its primary tasks the realization of a Global Survey of Scientists that will provide updated information on this situation not only about physics but also about mathematical, computing and natural sciences.

3.6   New guidelines for the IUPAP. Based on the general discussions at ICWIP, the Working Group elaborates recommendations and resolutions to be presented at the IUPAP General Assembly to be upheld by the union. Among the several recommendations that had a direct impact on IUPAP policies were: to include women in its commissions; to enforce that women be among invited speakers and serve on conference committees;

to require that conferences had an associated outreach activity; to consider women for prizes and awards. Recommendations and resolutions can be found on the group's website, and also in the conference proceedings that are published after each ICWIP Hartline and Li [2002], Hartline and Michelman-Ribeiro [2005], Hartline, Horton, and Kaicher [2009], Cunningham [2013], and Cunningham, O'Riordan, and Ghose [2016].

More recently, the IUPAP has also decided to appoint one of its Vice-Presidents at large as Gender Champion. The role of this VP is to liaise with the Working Group to suggest gender-related policies to the Executive Committee and to oversee that they are observed. The existence of this position proved to be key in establishing new guidelines for IUPAP sponsored or endorsed conferences, among them, the requirement that at least 10% of the invited speakers and of conference committee members should be female, that all conferences should have someone appointed to handle problems of harassment and that a special session on inclusion and diversity in physics should be included.

4   Discussion

Several questions were raised and answers were variously given by the chair, the panelists and people in the audience. We include some of them in what follows.

It seems that there are more women in mathematics in less developed countries than in more developed countries, is it really so ?   It is certainly the case in many less developed countries, but not all. In Iran for example there are many women in mathematics, and it is also the case in several Asian countries, but it is much less so in Africa. It maybe related to the prestige of mathematics in a given country. Most of the time, the more prestigious the position, the less women! On the other hand, to have childcare or household help in developed countries is much more expensive than in less developed ones. There are also cultural differences to take into account. Both in the more developed and less developed countries, the percentage of women drops as we advance in the academic career. This phenomenon is similar in mathematics and in physics.

Is there a difference in the proportion of women in different areas of mathematics? If it is so, why ?   The number of women in a specific area seems to have a lot to do with a major figure in the subject in the past, woman or man, encouraging women's participation. Some subfields are more congenial to young people, to women. Rather than asking women to be able to compete like men do, we need a more friendly atmosphere in the community that allows and values other types of behaviour. Maybe the values and the sociology of the community need to be revised so that it becomes more women-friendly and more inclusive in general.

Everbody agrees that we need women role models, but when we look at the prizes awarded by the ICM in 2018, we do not see any woman. Are there initiatives to

push IMU for giving prizes to women ?   There are efforts to have more women speaking at ICM. We have seen that there has been a change, the proportion of women speakers is about 15% now. Prizes are another issue since each committee works independently. In the prize committees, the percentage of women is reasonable. But, as we have seen, women in committees does not imply women receiving prizes. It is important to nominate women. If you believe in an outstanding woman, you need to make sure she is nominated. Very often the committees do not receive enough female nominations.

On the stage there were no woman prize winner, but five women were present: one banker representing a sponsor and four women helping from the staff. What image does that give to the young Olympiad medalists in the audience?   Indeed, it was a real caricature. In ICM Seoul, Ingrid Daubechies, IMU president, Park Geun-hye, President of Korea, and Maryam Mirzakhani, first woman Fields medalist on stage at the same time made a great picture of three strong women together! Unfortunately this great event remains a singular isolated point.

Should not we force a gender balance for the composition of committees?   The committee percentages were not so bad. IMU, LMS and other organisations are making a lot of effort to have women in their committees. A complete balance would become impossible for the women researchers, as there are currently many fewer women than men.

Often, even women do not think of women, they think of men to nominate. How do we organize ourselves for prizes and committees? We need guidelines.   It is true that often both men and women prefer men. This phenomenon is well documented. Identical job applications for academic positions submitted with one female name /one male name had different answers to the advantage of the male name, even though the evaluators included women! We need to modify such unconscious biases.

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