Chapter 10
Framing Mathematical Excellence

Today's International Mathematical Union (IMU) derives its greatest visibility among mathematicians world wide from the International Congresses. Its very foundation was an integral part of the mounting of the first postwar ICM at Harvard in 1950. It is via the experience of the quadrennial ICMs and the published traces they leave behind that an image of mathematics continues to be framed and projected for the mathematical community at large, and for the whole world to see. In this final chapter we present a data-based study of how the most exquisite layer of this image has evolved over the past seventy years.

The hard core of this chapter—see Sections 10.3–10.5 below—presents and interprets a data-analysis realized for the occasion by Birgit Petri, Darmstadt. I am very much indebted to her for her relentless work on this project, and express my cordial gratitude.

Before focussing on this, though, let us sketch the overall structure of the IMU, and the activities of its associated bodies (apart from ICMI, which we have already considered in the preceding chapter).

10.1 The Infrastructure of the IMU

Among all the scientific unions assembled today under the umbrella of the International Science Council (ISC),[1] the IMU may well be the one with the most slender organigram. One could be tempted to explain this by the very nature of mathematics. In fact, even though stunning discoveries do exist in the world of mathematics—recall for example the *exotic spheres* uncovered by John Milnor (b. 1931) and Egbert Brieskorn (1936–2013), which stirred quite a bit of excitement in the late 1950s and 1960s—this is a far cry from naming and monitoring near-earth asteroids that might collide with our blue planet, which is one of the responsibilities that the International Astronomical Union (IAU) is involved in through its *Minor Planet Center*:

[1] See the list of Category 1 (Full Members) of ISC at [URL 29].

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> The Minor Planet Center (MPC) is the single worldwide location for receipt and distribution of positional measurements of minor planets, comets and outer irregular natural satellites of the major planets. The MPC is responsible for the identification, designation and orbit computation for all of these objects. This involves maintaining the master files of observations and orbits, keeping track of the discoverer of each object, and announcing discoveries to the rest of the world via electronic circulars and an extensive website. The MPC operates at the Smithsonian Astrophysical Observatory, under the auspices of Division F of the International Astronomical Union (IAU).[2]

The elusive nature of mathematical objects is not sufficient, though, to explain the slim infrastructure of the IMU. The end of the above quote contains an indication that the whole internal organization of the IAU is much more complex than that of the IMU; the Minor Planet Center belongs to *Division F* of the IAU, which is just one among nine different Divisions, each of which in turn counts several Commissions and Working Groups:[3]

- Division A Fundamental Astronomy
- Division B Facilities, Technologies and Data Science
- Division C Education, Outreach and Heritage
- Division D High Energy Phenomena and Fundamental Physics
- Division E Sun and Heliosphere
- Division F Planetary Systems and Astrobiology
- Division G Stars and Stellar Physics
- Division H Interstellar Matter and Local Universe
- Division I Galaxies and Cosmology.

This shows that the IAU has chosen—in fact, right from its beginnings, and partly building on pre-World-War-I specific networks of international collaboration—to mirror major dividing lines of the discipline in its administrative structure.[4] Several other scientific unions do the same. To name but one more example, the International Union of Geological Sciences (IUGS) counts among its constituent scientific bodies the International Commission on Stratigraphy (ICS), whose primary objective it is

> to define precisely global units (systems, series and stages) of the International Chronostratigraphic Chart that, in turn, are the basis for the units (periods, epochs and age) of the International Geological Time Scale; thus setting global standards for the fundamental scale for expressing the history of the Earth. The work of the Commission is divided between seventeen subcommissions, each responsible for a specific period of geological time. Their work is overseen and co-ordinated by an executive of five officers.[5]

Unlike these scientific unions, the IMU has never attempted to express the diversity of the mathematical sciences in its administrative structure. As far as I know, the division between pure and applied mathematics, which caused so many tense situa-

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[2] See [URL 30].

[3] See [URL 31].

[4] Besides, as briefly mentioned in 6.2.2 above, the IAU also distinguishes itself from the IMU and most other international scientific unions by having many individual members.

[5] Quoted from the heading of [URL 32]. Note in passing that the IUGS was founded only in 1961; it is a member of the ISC alongside the International Union of Geodesy and Geophysics (IUGG), whose foundation in 1919 we have mentioned in Section 4.1.1.

tions in numerous institutions and countries during the second half of the twentieth century, seems not to have been considered a reason for an internal administrative divide of the IMU.

Meanwhile ICIAM, the *International Council for Industrial and Applied Mathematics*, came into being in 1986 in the form of a standing committee for the organization of the quadrennial *International Conferences on Industrial and Applied Mathematics*, through an understanding of the principal societies for applied mathematics: GAMM, IMA, SIAM and SMAI. Thirteen years later this committee grew into a society of societies with an increasing number of members. In contrast to the IMU, however, ICIAM does not belong to the International Science Council (ISC).

There are only three Commissions subordinated to the IMU: the *International Commission for Mathematical Instruction* (ICMI), which we have discussed in Chapter 9, the *Commission for Developing Countries* (CDC), and the *International Commission on the History of Mathematics* (ICHM). Furthermore, apart from the IMU *Executive Committee* and other purely administrative committees, three IMU Committees (i.e., structures of a possibly less perennial nature than the Commissions) are currently active: the *Committee for Electronic Information* (CEIC), the *Committee for Women in Mathematics* (CWM), and the recently instituted *ad hoc Committee on Diversity* (CoD), whose first report is expected for the 2022 ICM.[6]

Before returning in Section 10.2 to the central focus of the IMU: the ICMs, we now briefly present the substructures that have not been discussed yet.

10.1.1 The Committee for Electronic Information and Communication (CEIC)

Recall that, throughout their history, the general assemblies of the ICMs and of the IMU had repeatedly tried to add genuine issues to their agendas, particularly concerning questions relating to the reviewing and bibliography of the rapidly exploding number of publications.[7] However, not only were most of the ICMs before 1950 organized independently of the IMU, but also throughout the twentieth century, neither the first nor the second IMU played an important part in advancing those classical bibliographic projects.

There is only one exception to this general verdict, which is rightly stressed in [Lehto 1998], p. 95: the initiative—which did arise in the context of various bibliographical projects—of a global Directory or index of mathematicians (WDM). The project was decided at the first General Assembly of the IMU at Rome in 1952 and was a success for almost half a century.[8]

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[6] See [URL 33].

[7] Cf. Sections 1.4.1.2, 4.1.1, and 4.3.2 above.

[8] Cf. [Lehto 1998], Section 6.3 for an account of the first forty years of WDM.

In this sense the creation of CEIC in 1998 was a fresh initiative. It came about in reaction to the new, electronic world of publishing, and communication in general. The Berlin ICM in 1998 congratulated itself several times on being the first to be organized and realized essentially via email.[9] The General Assembly of the IMU at Dresden that preceded the Berlin ICM thus adopted an "enabling resolution" to form a Committee on Electronic Information and Communication, which begins like this:

> 1. In the last decade, the internet has been transforming our communication and commerce. In the world of science, the internet is radically changing the modes of information transfer at all levels. Communication on hand-written and printed paper, distribution via postal mail and libraries is a system which has been stable for many centuries. We cannot foresee clearly the new system which is evolving except that it will involve electronic media and it will radically alter the economics of communication. This transformation will certainly be global and will affect mathematical research on all continents.
>
> 2. We strongly believe that the IMU can play several important roles during this transition. Among these are:
>
> i) it can provide a forum where all parties, i. e., all countries and all interest groups (individual researchers, professional societies, publishers, and libraries) can discuss the issues and it can publish proceedings to increase general understanding of all the issues involved,
>
> ii) it can recommend and promote international standards on electronic communication among mathematicians, when needed,
>
> iii) it can act as a liaison between regional, national and local groups, coordinating their initiatives and discussions.[10]

The CEIC webpage echoes this mission:

> The Internet, and the World Wide Web (WWW), have transformed mathematical communication in at least as great a way as the introduction of journals. This transformation affects all disciplines, and many of the resulting commercial pressures are beyond the control of mathematicians. Nevertheless mathematics, by its intrinsic nature and world-wide scope, has to develop a particular approach to this new situation. Changes have occurred very rapidly, and some of the habits of mathematicians—such as citation conventions, ways of building reputation, and for many mathematicians, very significant matters like promotion and working conditions—are still evolving in response to continuing changes. The IMU's Executive Committee therefore formed the Committee on Electronic Information and Communication (CEIC) in 1998 to watch these developments, to advise the EC, and through it the IMU and mathematicians generally, about these trends, and to find the best ways of evolving practice to adapt to these changes.[11]

In 2006, a specific idea was articulated:

> With the ultimate goal of creating an enduring network of digital mathematical literature, the General Assembly of the IMU endorses the new version of the "Best practices" document of its Committee on Electronic Information and Communication (CEIC), posted June 2005 . . . , as well as the March 2005 draft of "Digital Mathematical Library: a vision for the Future". The digital mathematical library is a very important project that we need to do as much as we can to further.[12]

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[9] See Proceedings ICM 1998, Vol. 1, pp. 27, 31, and 53.

[10] See Proceedings ICM 1998, Vol. 1, p. 54.

[11] Slightly amended clipping from [URL 34].

[12] See Proceedings ICM 2006, Vol. 1, p. 47.

This Global Digital Mathematical Library was discussed at the 2014 and 2018 ICMs. Meanwhile the whole process of scientific reviewing and publishing changed more quickly than many contemporaries had expected; but some were ready to react strongly.

> In 2012 Sir Tim[othy] Gowers [b. 1963], professor at Cambridge University, and thirty-three mathematicians from all over the world launched the movement “The Cost of Knowledge” and called to boycott Elsevier. They denounced Elsevier’s lobbying for the *Research Works Act*, a bill proposed to the American Congress aimed at prohibiting *open access* mandates for federally funded research and thus reversing the policy of the National Institute of Health (NIH), which requires taxpayer-funded research to be freely accessible online. The mathematicians of *“The Cost of Knowledge”* considered it was also their duty to design alternative publishing models to recover control of the peer-reviewed journals they create and use. In June 2012, they proposed the *diamond open access* model (a terminology inspired from the *Diamond Sutra*, a treasure of the British Library that was printed in 868 in China). This model assumes that researchers should not pay to publish their articles, and should own the journals they create and peer review.[13]

I recommend Marie Farge’s concise text—from which the preceding quote is taken—as a useful orientation in a debate which is far from settled. As for Diamond Access, one has to add the more recent information that in 2017, Elsevier bought Digital Commons-Bepress—which had originally been founded by researchers from Berkeley—and thus in a way also the label of Diamond Access.

The fact that Elsevier was explicitly targeted by the movement not only met with opposition from some colleagues, but potentially put the IMU into a difficult situation insofar as the official journal *Historia Mathematica* of the *International Commission on the History of Mathematics* ICHM (see 10.1.4 below) is published by Elsevier.

Marie Farge also criticizes the questionable spread of bibliometric indices. She mentions the IMU via Ingrid Daubechies’s blog of 2012:

> When alternative open access models will have proven to be effective (i.e., for the quality of articles they publish, the efficiency of their dissemination and financial viability), editorial boards might be able to emancipate existing journals. Indeed it might be necessary for a community of researchers to take back control of the best, and often the oldest, journals they use to publish their results. Emancipating a journal means that its intellectual property is transferred from the publisher to the editorial board, the publisher being then paid as service provider and no more the owner of the journal’s title, as proposed in 2012 by IMU (the International Mathematical Union).[14]

Rather than going into details of the ongoing debate among mathematicians, we invite the reader to consult the presentation of the *International Mathematical Knowledge Trust* (IMKT)[15], which is based on the corresponding panel at the 2018 ICM in Rio de Janeiro.

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[13] See [Farge 2017], p. 3.

[14] See [Farge 2017], p. 5. See the blog entries at [URL 35], in particular Ingrid Daubechies’s opening of this exchange.

[15] See [Ion et al. 2018].

To conclude this first mini-portrait of an IMU commission, it may not be superfluous to point out that commissions and their subject matters do not exist in separate bubbles. As for CEIC, both in view of the more than centennial history of Mathematics International and because of the immediate importance of publication for the professional life of mathematics, the IMU cannot but occupy itself and feel responsible for the best possible worldwide organization of the information stream of mathematical research. On the other hand the IMU is of course not at all the only organization which naturally has to attend to these issues. Other organizations concerned include for instance the International Science Council (ISC), and there are plenty of national or even regional, local or institutional agencies that all share in the responsibility of the mathematical publication system. That this intrinsic constellation is clearly reflected in the structure and in the concrete activities of the Committee for Electronic Information (CEIC), transpires, for instance, from the IMKT panel in 2018 that we mentioned. The same panel also shows the natural connection between CEIC and the IMU Commission for Developing Countries (CDC) that will be presented in Section 10.1.3 below.

Another natural connection which cannot currently be realized within the IMU is with deontological or ethical questions in the domain of publications, all the way from increasing problems—also in mathematics!—with plagiarism, to the slew of predatory journals and their business model of 'open access', which the individual researcher has to pay for.

10.1.2 Women in Mathematics

Emmy Noether died in 1935, shortly before her 53rd birthday. The following year, the first Fields Medals were awarded at the Oslo ICM. Even though the forty year age limit for the Fields Medal was only fixed in the 1950s,[16] speculating whether Emmy Noether could have been considered for a Fields Medal in 1936 had she lived longer is idle in the absence of documentary evidence; in fact, very little seems to be known about the work of the very first Fields Medal Committee.[17] Emmy Noether was awarded the prestigious Ackermann-Teubner Memorial Prize in 1932, jointly with Emil Artin, for their work on modern algebra; but this was a German prize, not the award of an international organization.[18]

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[16] See Michael Barany's analysis of this consequence of the selection process for the 1950 Medals in [Barany 2018].

[17] See [Hollings & Siegmund-Schultze 2020], p. 225–228.

[18] See [Rowe 2021], pp. 184–185.

As we all know, it was not until the Seoul ICM in 2014 that the mathematician Maryam Mirzakhani became the first woman to be awarded a Fields Medal. In 2014 the *glass ceiling*[19] of the mathematical profession was thus, for once, pushed up all the way to the cupola framed by the IMU. In March 2015, the creation of the Committee for Women in Mathematics (CWM) was approved by the IMU Executive Committee. Its first meeting was held in Italy in September 2015, thirteen months after the Seoul Congress. The CWM thus appears as a very recent body that tries to guide and influence the IMU and Mathematics International out of a long historical burden. It does, however, build on some forty years of initiatives to improve the representation of women mathematicians, at the ICMs and elsewhere.[20]

10.1.2.1 Poor statistics

There is a fallacious but instructive argument that was once developed by Emmy Noether's most successful student Bartel L. Van der Waerden, about the possible role of women in mathematics. We present it here because, although the author tried to mobilize a certain amount of sophistication, there is just one thing he blatantly failed to see and take into account[21]: the *glass ceiling* which tended (and still tends) to block women mathematicians from distinguished professional careers. The metaphor of the invisible glass ceiling thus proves its worth one more time.

In 1967, he set out to "prove" (!) in a letter to Ms. Auguste Dick (1910–1993)[22] that only a decisive biological factor can explain why there are so few women among the famous mathematicians and theoretical physicists. For his argument he only focussed on these two domains, which according to Van der Waerden had the advantage of excluding factors like access to laboratory facilities that could be more socially selective than the purely theoretical paperwork of mathematicians and theoretical physicists. Van der Waerden draped his 'proof' of the inferior mathematical talent of women in the form of a statistical test of the null hypothesis of equally distributed talent for mathematics, even though technical details like error margins and so forth are not given.[23]

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[19] We adapt this general concept from gender studies to the peculiar international constellation of mathematics. More generally, about the *Techo de cristal* in the world of mathematics, cf. the talks given (in Spanish) at the 2016 meeting *Women in Mathematics in Latin America: Barriers, Advancements and New Perspectives*; videos made available by the *Banff International Research Station* at [URL 36].

[20] For a condensed overview of such earlier initiatives, see [Mihaljević & Roy 2019], p. 118.

[21] We have mentioned a somewhat analogous criticism of politically charged statistics, which at the time was deconstructed by Messedaglia, in Section 1.1.5.1 above.

[22] Auguste Dick was the first biographer of Emmy Noether, see [Dick 1970].

[23] Van der Waerden is most famous for his textbook *Moderne Algebra*, and well-known among experts for his book on group theory for quantum mechanics, as well as for his contributions to algebraic geometry. However, he also developed early on a keen interest in applied mathematical statistics. This is reflected, besides his correspondence, in a number of articles as well as the textbook [Van der Waerden 1957]. In the mid-fifties he even organized a meeting on statistics at Oberwolfach.

erh. 11.3.67

Mathematisches Institut
der
Universität Zürich

CH 8006 Zürich, Rämistrasse 71
den 8.März 1967

Frau Dr.Auguste Dick
Marxergasse 18
1030 Wien

Sehr geehrte Frau Dr. Dick,

Besten Dank für die Zusendung Ihres sehr interessanten Aufsatzes "Die Mathematik und die Mädchen".

Die statistische Untersuchung, von der ich sprach, habe ich inzwischen durchgeführt. Ich habe mich dabei auf theoretische Physiker und Mathematiker beschränkt, die in den Jahren 1900 - 1950 studiert und in den Jahren 1910 - 1960 ihre grössten Leistungen vollbracht haben. Ich schätze, dass in den Jahren 1900 - 1950 mindestens 20 % der Studenten an europäischen und amerikanischen Universitäten Mädchen waren. Die"Nullhypothese", die wir prüfen wollen, ist die Hypothese, dass Knaben und Mädchen von Natur aus gleich begabt sind. Aus zwei genau gleichen Reservoirs von Knaben und Mädchen im Alter von 18 bis 20 Jahren werden also durch einen sozialen Selektionsprozess diejenigen ausgewählt, die nachher an den Universitäten studieren. Bei der Selektion spielt die Begabung eine grosse Rolle, aber auch soziale Gesichtspunkte und Vorurteile. Je stärker die Begabung, um so weniger spielen die sozialen Gesichtspunkte eine Rolle. Bei den Mädchen ist die Selektion strenger als bei den Knaben, also ist zu erwarten, dass die schliesslich zum Studium zugelassenen Mädchen im Durchschnitt etwas höher begabt sein werden als die Knaben (s.Figur).

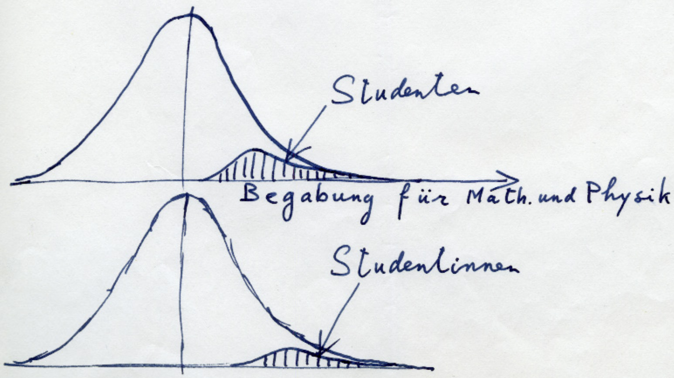

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Fig. 10.1 The first page of Van der Waerden's letter to Auguste Dick. Distribution of 'talent for mathematics and physics' among all students, resp. female students. Credit: [Arch. ÖAW].

I only consider theoretical physicists and mathematicians who were students between 1900 and 1950 and who realized their greatest achievements in the years 1910–1960. I estimate that in the period 1900–1950 at least 20% of the students [of mathematics or physics] at European and American universities were women. The 'null hypothesis' we want to test is

> that boys and girls are by nature equally gifted [in mathematics]. Starting from two equally big samples of boys and girls aged between 18 and 20, a process of social selection chooses those who will then study at a university. In this selection talent is a very important factor, but so are social aspects and prejudices. The stronger the talent the less effective will the social factors be. For girls this social selection is stricter than for boys; therefore it is to be expected that the girls who are finally admitted as students will on average be somewhat more talented than the boys.[24]
>
> Selecting now among the mathematicians and theoretical physicists of that period those with the most extraordinary achievements, our null hypothesis makes us expect more than 20% of them to be women.

Van der Waerden then goes on to list 35 names of excellent physicists sampled from recent source editions about the physics of the period in question, and finds not a single woman among them.

> Thus, among 35 leading physicists, there is no woman. For mathematics, there are no such editions of sources from which one may choose names. But if one would ask mathematicians from various fields to compile lists of leading mathematicians, I am sure that among the 25 or 30 best ones there would be only one woman: Emmy Noether. . . . In the end we obtain a list of
>
> $$35 + 25 = 60$$
>
> top mathematicians and theoretical physicists which contains only one woman.
>
> But according to our null hypothesis one would have to expect more than 20%, i.e., more than 12 women. Such a massive deviation cannot arise by chance. The null hypothesis thus has to be rejected.

Never mind the sketchy presentation of the argument, and the casual estimates of certain numbers or percentages; after all, he is writing a letter, not a research paper. The principal reason why Van der Waerden's argument lamentably fails to establish any biological factor whatsoever is that he never deigns to wonder about what it takes for a good student to manage a successful academic career. This fallacy he shared with very many people at the time, as I vividly remember from personal discussions. It took a lot of initiatives to start to curb this widespread attitude.

Without trying to go into details about the social mechanisms that create the *glass ceiling*, we do have to indicate how strongly the image of excellent mathematics shaped by the IMU was antagonistic to the role of women mathematicians. An overall analysis of the presence of women mathematicians at the ICMs has been attempted in [Mihaljević & Roy 2019]. The authors also mention a few factors that have influenced the career possibilities of women since World War II.

> It took 60 years to reach a share of women among ICM speakers comparable to that in 1932. Among the manifold reasons for this situation are undeniably the impact of some historical and political developments. The aftermath of World War II was characterized by a rollback in society as a whole. The 1950s experienced a return to conservative gender roles, in which

[24] This and the following quotes are from Van der Waerden's letter to A. Dick of 8 March 1967, [Arch. ÖAW], Nachlass Auguste Dick. I thank R. Siegmund-Schultze for having shared this original document with me; I had only been aware of the carbon copy, without the drawing, in [Arch. ETH], Hs 632:1854 (Van der Waerden papers).

> women were expected to take care of the domestic sphere, leaving the work places to the men who were coming back from the battlefields. These conceptions had impact on university education as well. During the conservative post-war era in Germany[25], for instance, the share of female students decreased significantly, and there was general agreement that men should take precedence in accessing the limited study places. However, some countries managed to overcome some of these barriers in women's university education and research faster than others. Partially, these general trends are also reflected in country-based differences regarding the presence of women speakers at postwar ICMs: in the 11 congresses between 1950 and 1990, of the 24 talks given by women, almost all delivered by speakers from the United States, France, United Kingdom, or Russia but none by speakers from Italy or Germany. By contrast, in the ten congresses before World War II of a comparable total of 27 talks by women, three of those speakers were from Germany and four from Italy.[26]

A more refined study of countries or world regions would obviously be very interesting. Overall [Mihaljević & Roy 2019] count 4,120 invited ICM contributions—all the way from 1897 to 2018—among which they determined (partly via automatic treatments, partly by hand) 202 that were presented or authored by women. This amounts to not quite 5% of the total. As indicated in the above quote, the variation over time is considerable, with no coherent trend over long periods.

In our approach, the database that will be explored in various directions in the present chapter was built to reflect the cupola of mathematical excellence framed by the IMU at the ICMs since 1950. It does not contain all the 4,120 speakers counted in [Mihaljević & Roy 2019] but is restricted to plenary speakers, prize winners as well as those who gave a laudatory address for a prize winner. On the other hand, next to these speakers and prize winners, we equally take into account those who served on a program committee or a prize committee. Among these 540 persons, we find a total of 31 women: not even 6%. And also for our criteria the distribution over time varies considerably; one third of these women first entered our database because of a function they held at the 2018 ICM in Rio.[27]

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[25] The authors clearly refer to West Germany here. A careful study of the career options of women mathematicians in countries of the Eastern Block during the Cold War would be interesting.

[26] See [Mihaljević & Roy 2019], pp. 117–118.

[27] Here is the complete list, ordered by the year of the first ICM [in parenthesis] where they acted in a function which brought them into our database. Within each ICM, the order is determined by the function: Fields Medalists, their laudatory speakers, and members of the Fields Medal Committee go first; before plenary speakers and members of the Program Committee; followed by people related to the Nevanlinna Prize; and the Gauss Prize—see also 10.3 below. Mary Lucy Cartwright [1958; 1 person]; Joan S. Birman, Karen Uhlenbeck [1990; 2]; Ingrid Daubechies, Marina Ratner [1994; 2]; Dusa McDuff [1998; 1]; Frances Kirwan, Sun-Yung Alice Chang, Shafi Goldwasser, Michèle Vergne [2002; 4]; Claire Voisin, Margaret Wright [2006; 2]; Irit Dinur, Raman Parimala, Kim Plofker , Eva Tardos [2010; 4]; Maryam Mirzakhani, Vera V. Serganova, Hélène Esnault, Barbara Keyfitz [2014; 4]; Alice Guionnet, Hee Oh, Lai-Sang Young, Sylvia Serfaty, Nalini Anantharaman, Catherine Goldstein, Ulrike Tillmann, Laure Saint-Raymond, Maria Esteban, Motoko Kotani, and Bin Yu [2018; 11].

Just as in the work by Mihaljević and Roy, our data equally reflect the extreme underrepresentation of women after World War II.[28] For instance, at the four ICMs between 1966 and 1978, not a single woman met the criteria for being entered into our database. And the ICMs between 1966 and 2002 brought a total of 347 persons into the base, only 9 of whom were women, i.e., hardly 2.6%.

After Emmy Noether's plenary lecture at Zürich in 1932, the world had to wait 58 years, until 1990 in Kyôto, to see another woman give a plenary talk at an ICM: Karen Uhlenbeck (b. 1942). At that same ICM, Joan S. Birman (b. 1927) was the first woman to deliver a laudatory talk for a Fields Medalist: Vaughan F.R. Jones (1952–2020).

10.1.2.2 The Emmy Noether Lectures and the IMU

It is one thing to bemoan the poor statistics, i.e., the glaring underrepresentation of women in mathematics, and another to take action. The Association for Women in Mathematics (AWM) in the US seems to have been the first organization to take action specifically in favor of women in mathematics.[29] It came into being after a group of women formed a caucus at the Joint Mathematics Meetings in Atlantic City in 1971.[30]

> In those years the AMS was governed by what could only be called an "old boys network," closed to all but those in the inner circle. Mary [W. Gray (b. 1939)] challenged that by sitting in on the Council meeting in Atlantic City. When she was told she had to leave, she refused saying she would wait until the police came. (Mary relates the story somewhat differently: When she was told she had to leave, she responded she could find no rules in the by-laws restricting attendance at Council meetings. She was then told it was by "gentlemen's agreement." Naturally Mary replied "Well, obviously I'm no gentleman.") After that time, Council meetings were open to observers and the process of democratization of the Society had begun.

In March 1982, the AWM organized a Conference for the centennial of Emmy Noether's birth, at Bryn Mawr College, i.e., at the place where she had last worked.[31] Already two years earlier, at the San Antonio meeting in January 1980, the AWM Emmy Noether Lectures (chaired first by Karen Uhlenbeck) were inaugurated by Jessie MacWilliams (1917–1980). This series of lectures continued at the January meetings of the AMS. The first twelve lectures were given by Jessie MacWilliams, Olga Taussky-Todd, Julia Robinson (1919–1985), Cathleen S. Morawetz (1923–2017), Mary Ellen Rudin (1924–2013), Jane Cronin Scanlon (1922–2018), the

[28] Cf. the case study for France [Menger et al. 2020], which highlights, pp. 207–211, the extreme underrepresentation of women in mathematics in comparison with other sciences.

[29] See for instance [Barrow-Green 1994], p. 129, and the literature cited there.

[30] Cf. the particularly rich and varied September 1991 "Special Issue on Women in Mathematics" of the *Notices of the American Mathematical Society* (Vol. 38, No. 7) on the occasion of the twentieth anniversary of the AWM. See specifically Lenore Blum's account of the founding of the AWM, p. 740, from which the following quote is taken.

[31] See the special issue of the *Notices AMS* already quoted, pp. 744–748.

French mathematician Yvonne Choquet-Bruhat (b. 1923), Joan S. Birman, Karen K. Uhlenbeck, Mary F. Wheeler (b. 1938), Bhama Srinivasan (b. 1935), and Alexandra Bellow (b. 1935).[32] In April 2013 the lecture was renamed the "AWM-AMS Noether Lecture", and in 2015 it was jointly sponsored by the AWM and the AMS.

Extending this recurring American event to the international scene, the AWM would hold special Emmy Noether Lectures at ICMs starting in 1994. Thus the Russian authority on partial differential equations Olga Ladyzhenskaya would give an Emmy Noether Lecture at the 1994 ICM in Zürich. She is indeed listed as one of the participants of that Congress, but I have been unable to find any mention of this lecture of hers in the Proceedings. In particular, this Emmy Noether Lecture is not mentioned by the President of the Congress Henri Carnal (b. 1939) in his opening speech, even though he did mention Emmy Noether's plenary ICM lecture of 1932, and continued, apparently trying to be funny:

> I am therefore happy to observe not only that the number of plenary lectures by women will this time be greater than 0, and even greater than 1, but also that the highest federal and cantonal authorities are both represented here by women. This shows that we can always hope for positive changes![33]

Four years later in Berlin, the Emmy Noether Lecture did make it into the ICM Proceedings, in the weak sense that it was explicitly mentioned in Martin Grötschel's opening address, if only after comments on the social program of the Congress, and among events that "would not fit elsewhere":

> In accordance with the Program Committee and the IMU, the Organizing Committee opened a Section of Special Activities to cover topics of mathematical relevance that would not fit elsewhere in the official scientific program. These special activities included an afternoon session on electronic publishing with three talks and a panel discussion on "The Future of Electronic Communication, Information, and Publishing"; presentations of mathematical software on three afternoons; several special activities related to women in mathematics including the Emmy Noether Lecture given by Cathleen Synge Morawetz, and a panel discussion "Events and Policies: Effects on Women in Mathematics"; an afternoon on "Berlin as Centre of Mathematical Activity" (this workshop was suggested by the International Commission on the History of Mathematics); a roundtable discussion on "International Comparison of Mathematical Studies, University Degrees, and Professional Perspectives".[34]

As for 2002, the Proceedings of the Beijing ICM fail to mention Hu Hesheng's (b. 1928) Noether Lecture. However, that year marks the beginning of the integration of these lectures into IMU policy:

> The IMU General Assembly in Shanghai 2002 had adopted the following Resolution 5: "The General Assembly recommends continuing the tradition of the 1994, 1998, 2002 ICMs, by holding an Emmy Noether lecture at the next two ICMs (2006 and 2010), with selection of the speakers to be made by an IMU appointed committee."[35]

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[32] Following the same special issue of the *Notices AMS*, p. 746. For the complete list, see [URL 37].

[33] See Proceedings ICM 1994, vol. 1, p. xxi.

[34] See Proceedings ICM 1998, vol. 1, p. 17.

[35] From the historical notes in [URL 38].

Even though such a committee was duly created for the Madrid ICM[36], the fact that Yvonne Choquet-Bruhat was chosen and gave the Emmy Noether Lecture was only mentioned in passing in the opening address of the President of the Congress, a bit like in Berlin back in 1998:

> Many other special activities were organized, a list of which would be too long to include in this introduction, although we may mention the scientific part of the Emmy Noether Talk, given by Ivonne [*sic*] Choquet-Bruhat, the special talk on Poincaré's Conjecture by John Morgan [b. 1946], and the talk given by Benoît Mandelbrot [1924–2010]. A joint scientific activity organized by the London Mathematical Society and the Real Sociedad Matemática Española was also held.[37]

The Hyderabad ICM of 2010 is the first ICM to include the Emmy Noether Lecture in the Proceedings, among the "Special Lectures." It was given by Idun Reiten (b. 1942) from Norway, on Cluster Categories.[38] The year also marked the decision to retroactively integrate earlier Emmy Noether Lectures given at—or rather: in the margin of—ICMs into the history of the IMU:

> At the General Assembly in Bangalore [in 2010] the Emmy Noether Lectures were adopted as a permanent ICM tradition via Resolution 8: "The General Assembly of the IMU recommends continuing the tradition of holding an Emmy Noether lecture at each ICM, with selection of the speaker to be made by a committee appointed by the IMU Executive Committee." To distinguish between the two series of Noether lectures it was decided to use the name ICM Emmy Noether Lecture for a lecture given at an ICM.[39]

The Emmy Noether Lecture in 2014 in Seoul was given by Georgia Benkart (b. 1949); in 2018 at Rio it was Sun-Yung Alice Chang's (b. 1948) turn. Today the ICM Emmy Noether Lecture is listed among the awards given by the IMU. It is a lifetime achievement award for women mathematicians. Yet, in view of its slightly complicated history as far as the IMU is concerned, we have decided not to include the lecturers, nor the corresponding committees, in our IMU database for the past seventy years. But in the future it will certainly have to be taken into account.

10.1.2.3 The Committee for Women in Mathematics (CWM) and its worldwide activities

The data we have quoted about the representation of women in Mathematics International show a difficult and irregular history, especially since 1967, when Van der Waerden wrote his letter to Auguste Dick. Looking at the last few years, though, in particular the short time span since the establishment of CWM in 2015, there is clear evidence that we are witnessing a new era. The numerous activities listed on the CWM website[40] conveys the kind of cultural internationalism that this Committee is working for and that is also reflected in the impressive list of the 150 CWM

[36] See Proceedings ICM 2006, vol. 1, p. 21.

[37] See Proceedings ICM 2006, vol. 1, pp. 10-11.

[38] See Proceedings ICM 2010, Vol. 1, pp. 558–594.

[39] From the historical notes in [URL 39].

[40] See [URL 40], as well as the activities reports posted on the site.

ambassadors.[41] The first *World Meeting for Women in Mathematics*, or $(WM)^2$ for short, took place in Rio as a satellite event of the 2018 ICM.[42] The second one is planned on the occasion of the 2022 ICM at St. Petersburg.[43]

This worldwide grassroots movement to the advantage of women mathematicians has at long last been built into the politics of Mathematics International backed by the IMU. But the women mathematicians' cause as we understand it today naturally undercuts divisions, headings and agencies which traditionally could be conceived of as separate concerns. Fighting the *glass ceiling* cannot limit itself to specific levels of education or career; the reflection has to address the whole spectrum, all the way from school education to the eligibility for the Fields Medal. And since the question of the career options for women mathematicians is intrinsically linked to cultural, national, and local constellations, the fight invites truly global networking. In this way, the CWM activities naturally meet with concerns pursued by ICMI and by the CDC.[44]

Furthermore, transversal connections about the cause of women in other directions extend well beyond the IMU. Under the roof of the International Science Council (ISC) an initiative has developed, which calls itself: *A Global Approach to the Gender Gap in Mathematical, Computing, and Natural Sciences. How to Measure It, How to Reduce It*. It involved mathematics, computing and several natural sciences.

> The mathematical and natural sciences have long benefited from the participation of excellent women scientists. However, at the end of the first decade of the twenty-first century, the percentage of women scientists remains shockingly low, and barriers to women's participation persist, leading to a gender gap at all levels and across all continents. It is against this backdrop that in 2016, the International Mathematical Union (IMU), through its Committee for Women in Mathematics, and the International Union of Pure and Applied Chemistry (IUPAC), supported by nine other ISC member unions and other partners, launched a project on the gender gap in science.
>
> The project comprised three main areas of research: a global survey of scientists, a databacked study on publications, and development of a database of good practice. The global survey asked scientists, both male and female, to reflect on their career experiences and any challenges they had encountered. It received responses from over 30,000 people in more than 150 countries, finding clear evidence for a gender gap in science.
>
> The project's second task was to develop an online tool to investigate the gender imbalance of scientific publications by women and men, across countries and fields of research. Shockingly, the study found that despite an increase in the proportion of women authors over time, women scientists were not publishing in top journals any more frequently than in the past, indicating that a gender barrier persists.

[41] See [URL 41].

[42] See [URL 42].

[43] See [URL 43].

[44] For an insightful presentation of many aspects of the problem we refer to the panel held at the 2018 ICM in Rio entitled: *The Gender Gap in Mathematical and Natural Sciences from a Historical Perspective*. See [URL 44].

> Finally, the project developed a 'database of good practices for girls and young women, parents, and organizations', to curate initiatives from all around the world that encourage the involvement of women in science. The database was made available on the IMU website in 2019, and is expected to expand in coming years.[45]

The Executive Committee of the initiative shows 23 members representing 11 bodies: The IMU, The International Union of Pure and Applied Chemistry (IUPAC), The International Union of Pure and Applied Physics (IUPAP), The International Astronomical Union (IAU), The International Union of Biological Sciences (IUBS), The International Council for Industrial and Applied Mathematics (ICIAM), The International Union of History and Philosophy of Science and Technology (IUHPST), UNESCO, the international initiative *Gender in science, innovation, technology and engineering* (GenderInSite), The Organization for Women in Science for the Developing World (OWSD), and The Association for Computing Machinery (ACM).

At a meeting at ICTP, Trieste, Marie-Françoise Roy commented: "We are happy with what we were able to do until now, but the long-term plan is to produce useful tools capable of living after the end of the project."[46] And in July 2020, it was decided to press ahead and set up the *Standing Committee for Gender Equality in Science*,

> a permanent organization formed by nine unions and partners that will start working in September 2020. Its goal will be to follow up the recommendations of the Gender Gap in Science project as well as maintaining and developing the tools created during the first years of the project.[47]

It has grown since its foundation and currently counts 16 unions as members.

Meanwhile, specifically for mathematics, the initiative launched by the 2018 meeting of $(WM)^2$ at Rio, to commemorate the twelfth of May, Maryam Mirzakhani's birthday, is now being followed by events in various parts of the world:

> For centuries women were disregarded as mathematicians, and the gender gap in mathematics remains very real. Celebratory events such as the ones supported by the May 12 Initiative bring about a crucial sense of belonging amongst women mathematicians and raise awareness throughout the entire mathematics community. The authors of this note belong to the coordinating group of the May 12 Initiative and tell the story of this international cooperation. We hope that next year you will join![48]

The Committee for Women in Mathematics is still rather young, so it will fall upon others to comment on its ongoing and future work. It may also be that the unquestioned bipolarity underlying our whole Section 10.1.2, which assumes a god-given dichotomy between two distinct genders and hence the possibility of sorting all mathematicians neatly into two disjoint drawers, will give way to an appreciation

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[45] See International Science Council, *Annual Report* 2019, p. 18.

[46] See International Science Council, *Annual Report* 2019, p. 18.

[47] See [URL 45].

[48] See [Agarwal et al. 2019], p. 1879.

of the social nature of the notion of gender, and its consequences for the professional world in and beyond mathematics. If this comes to be, mathematicians will have come a very long way since Van der Waerden's letter.

10.1.3 The Commission for Developing Countries (CDC)

In Section 8.2.1 we have already mentioned the early beginnings of today's IMU Commission for Developing Countries (CDC). Its first predecessor, the *Commission on Exchange*, existed from 1952 until the mid 1970s, when it was reshaped under the name *Commission on Development and Exchange*, or CDE for short. We have pointed out the paradigm shift that occurred within this quarter century, from a general sponsoring of individual mobility, by which the IMU could walk in the footsteps of the philanthropic activities of the interwar period, to an increasing attention to structural problems of developing countries. This shift is a reflection, within the worldview practiced by the IMU, of the era of decolonization.

The following quote is from a 1976 letter of A. John Coleman (1918–2010) to the President of the IMU Deane Montgomery (1909–1992). Coleman had been chosen as chair of the Commission on Exchange during the 1974 meeting of the IMU Executive Committee at Harrison Hot Springs, BC, Canada. He would subsequently be a member of CDE, from 1979 to 1982.

> I shall begin by apologizing for my lack of activity as Chairman of the Exchange Commission during 1975 which was due to unusual pressure of work, consequent upon a variety of commitments which I had undertaken before my appointment to the Exchange Commission. As you are aware, at Harrison Hot Springs the nature of the Commission was radically changed, and its mandate was transformed from that of arranging a modest number of high level mathematical lectures to that of mobilizing the mathematics departments in developed countries to give meaningful help to our colleagues in underdeveloped countries. At the ICM, I did call a meeting attended by about 40 mathematicians from underdeveloped countries to initiate the discussion about what could or should be done. That meeting generated considerable enthusiasm. Even before the ICM, Professor [Henri] Hogbe-Nlend [b. 1939] of Bordeaux had conceived the idea of a Pan-African Mathematical Conference. I am sure you are aware that plans are well advanced for it to be held in Rabat, Morocco at the end of July. Professor [Yukiyosi] Kawada [1916–1993] has explored the possibility of a similar conference for Asia. Professor [Bernhard H.] Neumann [1909–2002] has been assiduous in circulating the IMU Canberra Bullet which provides very useful information to the mathematical community.[49]

In Parts I and II of this book, we have pointed out characteristic evolutionary steps taken by the professionalization of science in general, and mathematics in particular. The mathematical researcher of the nineteenth century did not have an office; singular exceptions apart, he was male and he worked from home. He was connected with the civilised world by a postal service, which in European cities guaranteed more than one home delivery per day; letters within Europe were only marginally slower than

[49] See Coleman to Montgomery, 11 February 1976, [Arch. IMU], SF 7, F 5, IMU_004.pdf. Cf. [Lehto 1998], pp. 179–183, as well as pp. 263–273 for certain further developments in the 1980s.

email is today. Institute buildings were the next step, which—as far as mathematics was concerned—was taken in the twentieth century. Between the World Wars, when the exclusively European domination of world mathematics had ended, the traveling (young) scientist was invented on a large scale, and the concept of Locally-grounded Transnational Research Site (LGTRS) emerged from the emblematic example of the IAS at Princeton—see 5.2. This LGTRS concept would spawn an international, would-be global network—see Section 8.3 above. But only countries well advanced in national, regional, and local scientific infrastructures could afford a node of their own in that network. The first reaction of this expanding network with respect to countries that were not sufficiently developed to have their own LGTRS, was to invite the most promising young talents to one of the sites of the network, thus reiterating an older pattern of which we have seen a few examples in Section 6.4. The early activities of the IMU Commission on Exchange fit this larger pattern.

The *African Mathematical Union* was founded in July 1976 during the first Pan-African Congress of Mathematics at Rabat, Morocco, which is mentioned in the above quote from Coleman's letter. The first volume of the journal *Afrika Mathematica* of the African Mathematical Union was published in 1978.[50]

Also in 1978—after the strongest wave of decolonization in the twentieth century, at a time when the IMU was revising its policy towards developing countries—France founded CIMPA, the *Centre international de mathématiques pures et appliquées* (or ICPAM in English) in Nice, a new kind of institute that would cooperate with UNESCO and with the IMU.

> According to its statutes, its mission is the training of mathematicians coming in priority from developing countries, by means of study visits during the university academic year and of summer schools, and with the help of the development of means of documentations.[51]

A comparable institute had already been created in Trieste, Italy, for Theoretical Physics back in 1964 on the initiative of the Nobel Laureate Abdus Salam (1926–1996); the *International Centre for Theoretical Physics* (ICTP), which today is named after its founder. Its mathematical branch started to play its important part in bringing together mathematical talent from developing countries in 1986. In this way, two mathematical centers with an explicit concern for developing countries were appended to the web of LGTRSs.

In January 1985, Vol. 1 of the Joint Bulletin of the IMU's *Commission on Development and Exchange* (CDE) and CIMPA was published, in the form of bound mimeographed typescripts, with the financial assistance of UNESCO, under the name *Mathematics and Development*. The main objective of this publication was "to serve as a liaison bulletin between mathematical institutions in the developing countries." The first issues, which appeared twice a year, were exclusively devoted to the following two projects:

[50] The journal would be relaunched with a new editorial board in 2010.
[51] See [URL 46].

- Selective Bibliography of Mathematics.
- Mathematical Directory of the Developing Countries; starting with Africa and the Arab Middle East, which was structured according to English speaking African countries, French and Portuguese speaking African countries, Arab speaking African countries, and The Arab Middle East.

The Selective Bibliography project, "launched by ICPAM and adopted by the General Assembly of IMU in Warsaw (August 1982) and the General Conference of UNESCO (October 1983), is a program to help developing countries to start constitution of their libraries in Pure and Applied Mathematics and Computer Sciences, taking in mind their financial difficulties and the lack of specialists of these various disciplines in these countries."[52] Jean Dieudonné—since 1964 professor in Nice, where CIMPA was based—started this project by proposing a first draft of a *Bibliographie sélective* in two parts. The first part listed what Dieudonné thought were the most urgent items: a little less than 100 titles from all branches of mathematics chosen in such a way as to make it possible to prepare a one year course on each subject. The second part contained about 300 titles, the fitting ones of which could be acquired depending on which more advanced courses were planned. Dieudonné's list was subsequently circulated, and discussed further among a number of colleagues. Dieudonné starts out with the section "Periodicals and Series", in which the first item is all the *Lecture Notes in Mathematics* of Springer Verlag, followed by the *Proceedings of Symposia in Pure Mathematics* of the AMS, and the French *Astérisque*. This hefty onset, and other proposed items, would be modified by colleagues involved in the later discussions, for instance by Jean-Pierre Serre. It is not clear to me to what extent these projects matured or were realized. A current analog of this kind of project is the Global Digital Mathematical Library, which we have mentioned in Section 10.1.1 above.[53]

Donating libraries, offprint collections or books to institutions of learning in developing countries was and is a frequent practice, but mostly in the form of individual initiatives. Among the many activities of today's CDC, there is a *Library Assistance Scheme* that offers to coordinate donations.[54] At the same time, online resources have modified the situation quite a bit. In 2010–2011, the IMU joined the European Mathematical Society EMS in organizing a series of workshops about "Finding Online Information in Mathematics" held in Ethiopia, Mali, Mozambique, and Cambodia.[55]

In archival documents related to the prehistory of CDC, one frequently encounters remarks about the enormous challenge, and about the importance of not slipping into a patronizing attitude.[56] This is strongly echoed in various reports elaborated over the last fifteen years, dealing with the situation of mathematics in Africa, in Latin

[52] Quoted *verbatim* from Hogbe-Nlend's editorial to *Mathematics and Development*, Vol. 1 (1985).

[53] See also *Bulletin of the IMU* 64 (July 2014), Appendix II, pp. 47–50.

[54] See [URL 47].

[55] See [URL 48].

[56] Coleman makes this point on several occasions in his letters.

America and the Caribbean, and in South-East Asia.[57] Let us quote for instance from the 2009 report on *Mathematics in Africa: Challenges and Opportunities* to the John Templeton Foundation. This report was coordinated by the IMU's *Developing Countries Strategy Group* (DCSG), which had itself been set up in 2003/2004 as a corollary of renewed interest in these questions on the part of the IMU Executive Committee since 2002. The DCSG merged with the CDE in 2010, thus creating today's CDC.[58]

> Given the enormity of this challenge, one might ask whether there are individual steps that offer exceptional leverage to jump-start the enterprise as a whole. For example, one step might be a program to support students of exceptional talent, identified perhaps by their participation in the mathematics Olympiads. While sending such students to top international universities, for example, is likely to produce great benefits for individuals, it was not suggested by our advisors. They felt unanimously that no "magic bullet" or quick fix could solve a problem that is systemic and institutional. Such a program might raise the visibility of mathematics among secondary school students, but this benefit could be reduced should privileged students decide to remain abroad rather than return home to unrewarding positions.
>
> The second suggestion is to *strengthen and expand successful training and research activities, especially regional networks of people and institutions.* There are several reasons our advisors highlight this option. First, successful networks by definition involve leaders of demonstrated talent and institutions capable of supporting creditable mathematics programs. Second, supporting a network helps build a critical mass of students and faculty who are otherwise likely to be professionally isolated. Third, by building on institutions and people already in place, networks use tools that are relatively inexpensive in relation to their power, such as partnerships, mentoring, distance learning, and internet-based collaboration.[59]

We invite the reader to browse the rich website of the CDC[60] and discover its current programs and activities, such as for instance the Volunteer Lecturer Program (VLP), which was established in 2008. It offers financial assistance to universities in developing countries to host a volunteer lecturer for an intensive course of several weeks.

Not less informative, often richer in detail, but a rather different type of text altogether, is the 2014 White Paper: "The International Mathematical Union in the Developing World: Past, Present, and Future," which was produced "for policy makers, funding agencies, constituencies of the IMU and ICMI, and for others who would like to learn more about the activities and objectives of the IMU."[61] The vantage point of this White Paper is the observation that it is—or it ought to be—in the best interest of every national government to improve the state of its mathematical education and profession at all levels.

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[57] See [URL 49].

[58] For an overview of the achievements of the DCSG, see [URL 50].

[59] See [URL 51].

[60] See [URL 52].

[61] See the 64th *Bulletin of the International Mathematical Union*, July 2014, Appendix II, pp. 23–54. It is accessible at [URL 53].

10.1.4 The International Commission on the History of Mathematics (ICHM)

International scientific unions that have joined ICSU (in the past), resp. the ISC (since 2018), come in various forms. An interesting example is given by the *International Union of the History and Philosophy of Science* (IUHPS), which itself has expanded in 2010 into the *International Union of the History and Philosophy of Science and Technology* (IUHPST).

> There had been a long succession of international conferences of history of science and of philosophy of science since the beginning of the [twentieth] century. The historians [of science] founded their Union in 1947 and adhered to ICSU. The International Union of the Philosophy of Science IUPS was founded in 1949, but had not been admitted to ICSU by the time of the 1949 Fifth General Assembly. The two joined forces in 1956 to act as two divisions of one Union. IUHS had already developed several scientific sections and was to multiply them as time went on. Since many Unions have members with an interest in the history of their own science, Joint Commissions with some other Unions were also created. Enough to say that the way IUHS later merged into IUHPS is characteristic of the evolutionary character of many Unions.[62]

The Joint Commission to be discussed in the present section is attached both to the IUHPST and the IMU. It is the only Commission of the IMU that depends jointly on two international scientific unions. Since the IUHPST is the disjoint union of its two divisions: the *Division of History of Science and Technology* DHST and the *Division of Philosophy of Science and Technology* DPST, the *International Commission on the History of Mathematics* (ICHM) is in fact a joint commission of the IMU and the DHST.

ICHM was originally founded in 1971 by the DHST, which at the time—before the adjunction of the history of technology—was still simply the *Division of History of Science*, DHS. The DHST continues to be ICHM's primary affiliation; the commission continues to receive its basic annual grant from the DHST, and the official meetings every four years of the ICHM take place as part of the DHST international congresses.[63] The history of the ICHM is wrapped up in the congresses of the DHST: in Moscow (1971), Tokyo (1974), Edinburgh (1977), Bucharest (1981), Berkeley (1985), Hamburg & Munich (1989), Zaragoza (1993), Liège (1997), Mexico City (2001), Beijing (2005), Budapest (2009), Manchester (2013), Rio de Janeiro (2017), and the Congress at Prague, which had to be held online in 2021.

The ICHM achieves its greatest visibility through its official journal, *Historia Mathematica*. This journal was founded in 1974 by Kenneth O. May (1915–1977) in Toronto, who had earlier been one of the instigators of ICHM, and who published, jointly with Constance M. Gardner, the first edition of the *World Directory of Historians of Mathematics* in 1972. *Historia Mathematica* (or HM for short) publishes

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[62] See [Greenaway 1996], pp. 79–80.

[63] Here and in the remainder of this Section, I rely on freely accessible information from the ICHM website [URL 54], which is embedded in the IMU website, as well as on personal communication from Craig Fraser and June Barrow-Green, the former and the current chair of the ICHM. Hearty thanks to both of them.

original research on the history of the mathematics of all periods and in all cultural settings. The journal is published by Elsevier and provides some funding for the ICHM.

At the International Congress of History of Science at Berkeley in 1985, the ICHM voted to approach the IMU regarding re-establishing itself as an inter-union commission between the IHPS(T)/DHS(T) and the IMU. This Joint Commission was established in 1987 following a ballot of members of the IMU, and began its work at the beginning of 1988. The DHST does not appoint representatives to the ICHM, because everyone on the Executive Committee of the ICHM, with the exception of the IMU representatives and the HM editors, is in some sense already part of the DHST. At present the ICHM counts 44 member countries.

In the last four years the ICHM has integrated itself somewhat more closely with the IMU from an operational point of view. Since 2018 the IMU arranged to include the ICHM accounts within their financial umbrella. Similarly the ICHM website is now managed by the IMU.

By comparison, the history of chemistry and of physics are sole commissions of the DHST, and are not part of the international unions for these sciences. The history of ancient astronomy left the International Astronomical Union and became a commission solely of the DHST, primarily because it felt that the IAU was not professional enough in its understanding of the older history. Occasionally there may have been concerns at the ICHM about the view of history held by working mathematicians and expressed to some extent in the IMU.

André Weil, for example, in his plenary lecture: "History of Mathematics: Why and How?" at the Helsinki ICM in 1978, stressed the history of ideas as the focal approach to the history of mathematics and concluded that "the craft of mathematical history can best be practiced by those of us who are or have been active mathematicians or at least who are in close contact with active mathematicians."[64]

This point of view almost seems to echo the indignation of the historian of mathematics Moritz Cantor addressing the history section of the Heidelberg ICM in 1904, who had serious doubts about a general history of the exact sciences. For him, the peculiarities of the various scientific disciplines made it inconceivable that a chemist by training and a mathematician by training could reasonably compete for the same history chair.[65]

By 1978, however, the community of historians of science, and of mathematics, had come a long way since the days of Moritz Cantor, and Weil's lecture, in spite of its erudition and in spite of the author's obvious sense of history, would provoke mixed feelings in the community of historians of mathematics, especially also among those who had themselves at some point left mathematical research and resolutely reoriented themselves as historians of mathematics.

[64] See Proceedings ICM 1978, Vol. 1, p. 234.

[65] See Proceedings ICM 1904, pp. 500–501.

Yet, ever since it became a joint commission, the ICHM has continued to maintain the link with the mathematicians. Thus the history of mathematics differs from the history of physics, chemistry and biology in being part of the associated disciplinary international union.

The ICHM co-sponsors events of high intellectual caliber with a view to encouraging quality research in the history of mathematics. ICHM co-sponsorship does not necessarily involve financial support, but applications for limited funding may be made. Special consideration is given to events organized by and/or for early career scholars. A recurring annual event based in Europe, which has been co-sponsored by the ICHM in recent years, is the so-called *Novembertagung* on the History of Mathematics. It is aimed at PhD and postdoctoral students in the history of mathematics and neighboring fields. The last five meetings were organized in Torino, Italy, in 2015, Sandbjerg, Denmark, in 2016, Brussels, Belgium, in 2017, Seville, Spain, in 2018, and Strasbourg, France, in 2019. The 2020 *Novembertagung*, organized by young researchers based in Berlin, had to be moved online.

At the International Congress of History of Science and Technology (ICHST) in 2017 at Rio de Janeiro, three Symposia on the History of Mathematics were co-sponsored by the ICHM: on The Resurgence of Applied Mathematics 1850–1950; on Mathematical Methods at Work in Ancient China; and on Global Mathematics.

The distinguished prize awarded by the ICHM since 1989 is the *Kenneth O. May Prize and Medal* in the History of Mathematics. Two of these Medals are usually awarded every four years at the ICHST, to colleagues whose work best exemplifies the high scholarly standards and intellectual contributions to the field that K.O. May worked so hard to achieve. The bronze Medal was designed by the Canadian sculptor Saulius Jaskus. The first woman to receive the Kenneth O. May Prize was Lam Lay Yong (b. 1936) from Singapore, in 2001; the Medal was actually given to her during a ceremony at the Beijing ICM in 2002.

Explicitly directed at young career researchers is the *Montucla Prize*. Since 2009 it has been awarded by the ICHM at each ICHST, to the author of the best article published by a young researcher in *Historia Mathematica* in the four years preceding the Congress. The prize money is generated by revenue of the journal. The first woman to receive the Montucla award was Jemma Lorenat (b. 1987) in 2017.

10.2 Framing ICMs

In Section 8.2.1.1 we have divided the sequence of the 28 ICMs held between 1897 and 2018 into two intervals of approximately 60 years each: from 1897 to 1958, and from 1962 to 2018, the distinction between the two periods being the participation of the IMU in organizing ICMs. There was no IMU to claim a share in the organization of the first five ICMs, between 1897 and 1912. The old IMU existed between 1920 and 1932, under the roof of the IRC. This Council managed to uphold its exclusion politics at the Strasbourg ICM in 1920 and in Toronto in 1924. But the three following ICMs—at Bologna in 1928, Zürich in 1932, and Oslo in 1936—were again organized independently, in defiance of the IMU, the IRC and ICSU. This autonomy of the local Organizing Committees continued at the first three ICMs after World War II. During the 1950 ICM in Cambridge, Mass., the new IMU was still in the making. In 1954 in Amsterdam and in 1958 in Edinburgh, the new IMU was established, but had no say in the organization of those ICMs.

> The mathematical program was determined before the 1962 Congress by the local Organizing Committee, for the ICM-62 and thereafter by a Consultative Committee (CC), which in 1982 was renamed Program Committee (PC). The members of the CC and PC are appointed partly by the IMU Executive Committee, partly by the local Organizing Committee. For the ICM-62, the CC was still advisory to the OC; thereafter, it had the sole authority for the scientific program. Since the 1962 Congress, the President of the IMU appoints its Chairman. For the ICMs 1966, 1970, and 1974, the IMU Executive Committee and the local OC each appointed four of the eight members. For the ICMs 1978, 1983, 1986, and 1990, the local OC could appoint two, three, or four members according to the decision of the IMU Executive Committee, which appointed the rest. Since 1990, the IMU Executive Committee has appointed seven members, the local OC, two.[66]

Since the 2002 ICM in Beijing, the Program Committee always counted 11 or 12 members. In 2002, two of them were from China. Likewise at the Madrid ICM in 2006, there were two Spanish colleagues among the members of the PC. For the 2010 ICM in Hyderabad, and in 2014 in Seoul, there was only one local member on the PC, and none in 2018 in Rio de Janeiro.

The progression of the IMU towards increasing control of the ICMs was not always smooth and uncontested. Major challenges took the form of political allegations against the IMU. Recall for instance from Section 8.2.3 Pontryagin's and Vinogradov's criticism of the IMU during the preparation of the ICM in Warsaw. Claiming that the IMU was favoring Western mathematicians with "Zionist ideology," they asked for "the procedure in force before the Stockholm ICM" to be restored, when the national Organizing Committee could control things.

Olli Lehto has included in his book on the history of the IMU an interesting section on the mounting of the 1978 ICM in Helsinki, based on his personal involvement.[67] Instead of focussing here in a similar way on another ICM of the recent past, based on archival material, we pass immediately to a new Committee that was set up recently upon the initiative of the current Secretary of the IMU: the *Structure Committee* (SC). Its creation highlights both the importance of invitations for the speakers' careers and the difficulty of balancing branches of mathematics, sections, and personal preferences of members on the progam committee. Such issues will also be reflected in our data analysis, which will occupy the remainder of this final Chapter 10.

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[66] See [Lehto 1998], p. 320.

[67] See [Lehto 1998], Section 9.4.

Let us begin by quoting from the Guidelines for the ICM Structure Committee that were endorsed by the IMU General Assembly in 2018.[68]

> The International Congresses of Mathematicians (ICMs) are the most important IMU activity and need correspondingly careful preparation. Every ICM should reflect the current activity of mathematics in the world, present the best work being carried out in all mathematical subfields and different regions of the world, and thus, point to the future of mathematics. The invited speakers at an ICM should be mathematicians of the highest quality who are able to present current research to a broad mathematical audience.
>
> The ICMs have traditionally been organized in the form of a number of invited one-hour plenary lectures, to be held without other parallel activities. In addition, there is a number of sections defined in terms of different subfields of mathematics. In each section there is a number of 45-minute sectional lectures. The sections take place in parallel throughout the ICM. In addition, there are a small number of one-hour prize lectures associated with various prizes (Fields, Nevanlinna, Gauss, Chern, and Leelavati) and named lectures (Noether and Abel). The possible overlap of speaker for a prize lecture and plenary or sectional talk may result in changes in the program, as no person gives more than one talk at an ICM.
>
> Traditional target numbers are
>
> - 20 plenary lectures
> - 180 sectional lectures distributed over 18–20 sections
> - 10 prize and named lectures (in addition, there will be shorter laudatory talks in connection with the prizes)
>
> It is difficult to increase these numbers substantially without extending the duration of an ICM.
>
> The Structure Committee (SC) is responsible for the preparation of the Scientific Program of the ICM. It decides the structure of the Scientific Program, in particular,
>
> - the number of plenary lectures,
> - the sections and their precise definition,
> - the target number of talks in each section,
> - other kind of lectures, and
> - the arrangement of sections.
>
> The size and content of the sections should reflect the development of contemporary mathematics and should both reflect the importance and the volume of activity in the various subfields of mathematics.
>
> The prize lectures and named lectures cannot be altered by the SC. It is understood that the SC will employ the programs of previous ICMs as guidelines for its decisions. The SC may also propose other activities like discussion panels, non-mathematical talks, and talks aimed at the general public.
>
> If the SC wants to propose more radical changes in the structure of an ICM, it should make a proposal to the Executive Committee (EC), which then will decide in the matter.
>
> The responsibility to decide the speakers resides with the Program Committee.

Following work of an informal committee chaired by László Lovász, the inaugural Structure Committee was formed along the above guidelines in January 2019, with a view to preparing the 2022 ICM in St. Petersburg. Chaired by Terence Tao it counts

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[68] See [URL 55].

14 members and has delivered a very substantial report about their work achieved in 2019, largely on the basis of comments from the mathematical community at large.[69] Here is a short extract.

> Many of the lectures at [an ICM] play dual roles, serving both as a prestigious recognition for the lecturer, and as a scientific talk disseminating the most important advances in a given field. For instance, the various prizes given out by the IMU at the Congress, such as the Fields Medals, are perceived as amongst the highest recognitions available in mathematics, and receive extensive attention outside of the mathematical community as well; but each of the prize laureates also gives an hour-long lecture on their work that is attended by a large fraction of the entire Congress. Similarly, the 20 or so plenary lectures are also regarded as highly prestigious, and each such lecture commands the undivided attention of the Congress. ... [These] plenary lectures are expected to be somewhat broader in order to appeal to the less specialist audience, but are still mostly given by eminent mathematicians who have been closely involved in recent advances in the field.
>
> While many aspects of the Congress appear to have been generally well received ..., several issues with the Congress were repeatedly raised by a number of participants and organizers. One frequent complaint was that expository quality of sectional and plenary talks was highly variable ... This was a particular concern for the plenary lectures, given that no other activities for Congress participants were scheduled during these extremely high-profile talks. ...
>
> Another recurring concern was that the subdivision of all of mathematics into a section structure that has evolved only very slowly over time affected the breadth of topics covered, with talks in well established traditional areas being favored over emerging, experimental or interdisciplinary areas. Related to this was a widespread perception that the Congress caters more to the "pure" disciplines of mathematics than the "applied" ones, with many in the applied mathematics community feeling that the prestige of an invitation to speak at the Congress, or the value of attending such a Congress, is less than what it would be for a member of the pure mathematics community.

Constituted at the end of the period studied in this book, the Structure Committee epitomizes the fact that ICMs are today unquestionably controlled by the IMU. We have thus come a long way. ICM routines have emerged for more than a century; the IMU has intervened since 1962. Now the IMU is monitoring the organizational success with respect to a blueprint of ICMs which has crystallized over the past 120 years.

In the following sections, we shall probe the functioning of the ICMs of the past seventy years.

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[69] See [URL 56].

10.3 The Database

We shall now present the data-analysis that was realized for this book by Birgit Petri, Darmstadt. The aim of this quantitative investigation is to explore the image of mathematical excellency that the IMU has framed via its influence on the ICMs of the past seventy years. We are particularly interested in the way in which this image has changed over time.

As we saw in Section 8.2.1.1 and in the preceding section, the IMU took control of the organization of the ICMs only gradually. Since our analysis is based on ICM-related data, not everything we find necessarily reflects actions on the part of the IMU. This should be kept in mind when interpreting our results concerning the 1950s and early 1960s.

The Population Studied. We realized early on that the kind of quantitative analysis we were after would become too unwieldy if we included *all* speakers and committee members of all the ICMs since 1950.[70] Since our intention was to investigate the image of mathematical excellence projected by the IMU through the Congresses, we decided to isolate the top layer of all the ICMs between 1950 and 2018. Going through these 18 Congresses one by one, we thus restricted attention to those mathematicians who, at a given ICM, had one of the functions listed below. Note the underlying idea of symmetry of our criteria between those that are chosen and those that choose.

- Invited to deliver a Plenary Lecture.[71]
- Member of the Program Committee of the ICM.[72]
- Winner of the Fields Medal; Laudatory speaker on one (or more) Fields Medalist(s); Member of the Fields Medal Committee.
- Winner of the Nevanlinna Prize; Laudatory Speaker for the Nevanlinna Prize; Member of the Nevanlinna Prize Committee.[73]
- Winner of the Gauss Prize; Laudatory speaker for the Gauss Prize; Member of the Gauss Prize Committee.[74]

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[70] The study [Mihaljević & Roy 2019] looks at all the speakers of all the ICMs, since 1897. As a result, the amount of available information about the individual persons in that database varies considerably. For instance, the authors had to partially resort to automated guessing of the gender of the speakers listed.

[71] We enter these people according to the IMU website [URL 57], cross-checked against the Proceedings of the corresponding ICM. The list includes speakers who could not, or would not attend the congress to which they were invited. In the earlier ICMs of our time span, Plenary Lectures were called "One Hour Lectures."

[72] This information is usually based on the Proceedings of the corresponding ICM; occasionally on [Lehto 1998], App. 8.

[73] The Nevanlinna Prize was awarded once at every ICM from 1983 until 2018. Following protests concerning Rolf Nevanlinna's (1895–1980) affinities with Nazi politics, the prize is called the IMU Abacus Medal as of 2022.

[74] For the Fields Medal, the Nevanlinna Prize, and the Gauss Prize, the winners and members of the Prize Committees are listed on the IMU website; the Laudatory Speakers in the ICM Proceedings.

The Nevanlinna Prize / IMU Abacus Award is given for outstanding contributions in Mathematical Aspects of Information Sciences. Compared to the Fields Medal it thus represents an explicit widening of scope of the achievements honored by the IMU. The same is true of the Gauss Prize, which was created to honor scientists whose mathematical research has had an impact outside mathematics.[75]

There are three more recent awards attributed by the IMU, which we have not taken into account for our analysis: The Chern Medal Award and the Leelavati Prize, which have only been awarded since 2010, and the ICM Emmy Noether Lecture, which was discussed above in Section 10.1.2.2.

The great majority of the persons in our database: 313 out of the 540, have presented a total of 334 plenary lectures. Going through the list of ICMs, there are of course many individuals who served in different functions as time went on. For instance, 83 among the 182 members of the ICM Program Committees have also given at least one Plenary Lecture at some point in their career. There are only 9 of the 58 Fields Medalists since 1950[76] who have never given a Plenary Lecture, nor served on a Program Committee or a Fields Medal Committee. In 25 cases, the Laudatory lecturers for Fields Medalists came from the corresponding Fields Medal Committee.

The information stored for each person. For each of the 540 persons in our population, the database records a certain amount of information gathered from openly accessible sources.[77]

The *biographical information* about each person in our population includes: gender, last name, first name(s); ICM(s) and function(s) which made the person part of our population; sectional talks given at other ICMs, if applicable; year of birth[78], year of death (when applicable), place of birth[79], country of birth, citizenship(s) held. There is also a column for free comments on biographical features, such as migration history, involvement in war-related projects, functions held inside the IMU.

For each person in our population, another goal was to record the following information concerning their *PhD*[80]: year, title, institution, thesis-advisor[81], (classification of the thesis, if available), explanatory comments as needed.

[75] The Gauss Prize, which is jointly awarded by the IMU and the German Mathematical Society DMV, was founded in 2006.

[76] Only Grigori Perelman declined the Fields Medal offered to him in 2006. He is nonetheless kept in our database, which records decisions of the IMU.

[77] Information from Wikipedia entries (in various languages) was checked and fine tuned with the help of institutional or personal websites open to the public, as well as published material such as necrologies.

[78] In a few exceptional cases, this could not be determined precisely.

[79] Not always given precisely.

[80] In countries like USSR, France, Germany, etc., where there are two theses of different levels, “PhD” refers to the first thesis. Information from the *Mathematics Genealogy Project* [URL 58] was cross-checked as best we could by other openly accessible sources.

[81] Given with name, first name, years of birth and death.

For all lectures at an ICM presented by a member of our population—be they plenary or sectional lectures, lectures given in honor of Fields Medalists or winners of a Nevanlinna or a Gauss Prize—we record: the lecturer, year of the ICM, subject classification[82], and the type of lecture delivered. The title of the lecture is given as well, if it is available.[83]

For each person in our population, we tried to determine their professional *affiliations* as follows. To each ICM we associate a symmetric time interval of 9 years; for instance, the interval associated to the 1990 ICM in Kyoto contains the years 1986 through 1994. For all those who entered our data because of a function at a given ICM, we list their affiliations (institution and corresponding duration) that have a non-empty intersection with the associated interval around the ICM. Here "affiliation" is understood as employment on a potentially permanent basis. Furthermore, we also note temporary research sojourns—insofar as they can be determined from easily accessible information—and participation at conferences in Oberwolfach.[84]

Periodization. In order to structure the material as well as the evidence detected, we shall routinely group the past 70 years into 5 consecutive periods each of which contains either 4 or 3 ICMs. This periodization was already used in Section 8.2 above.

Period 1. 1950 Cambridge (Mass.); 1954 Amsterdam; 1958 Edinburgh; 1962 Stockholm.

Period 2. 1966 Moscow; 1970 Nice; 1974 Vancouver; 1978 Helsinki.

Period 3. 1983 (moved from 1982) Warsaw; 1986 Berkeley; 1990 Kyoto.

Period 4. 1994 Zürich; 1998 Berlin; 2002 Beijing.

Period 5. 2006 Madrid; 2010 Hyderabad; 2014 Seoul; 2018 Rio de Janeiro.

Some of the questions studied in the sequel require consideration of slightly shifted or regrouped time intervals. This will be explained as we go along. However, the periods above will remain the principal frame of reference as we look at the past seventy years.

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[82] According to the Mathematics Subject Classification (MSC) scheme. The relevant websites are [URL 59] jointly with [URL 60], and [URL 61], which indicates the classification at the time of publication. For laudatory lectures that are only classified under 'history, biography', we have determined an amended classification which reflects the mathematical subject.

[83] All this presupposes that we have sufficient information about the lecture. This is not always the case, for instance if a speaker actually did give a talk, but never submitted a manuscript. On the other hand, there were invited speakers who could not attend, but their talk was given by a proxy, or simply sent in as a manuscript.

[84] In this respect, Birgit Petri's survey actually went beyond the data that were finally used for this book. It also included activities as journal editors.

10.4 The Cupola of the ICMs

The population described in the previous section, about which we have collected all that information in our database, restricts attention to the most distinguished layer of mathematical achievements showcased at the ICMs. We call it the cupola of the ICMs.

10.4.1 Parts of the mathematical world

To get started it is instructive to look at the geographic distribution of our distinguished population, and how this changed over the five periods we have introduced above. In order to obtain such a global overview, diagrams showing all individual countries involved in the biographical data of our 540 mathematicians would be unreadable. On the other hand, certain individual countries are interesting to look at because they have been, or emerged as, leading countries on the mathematical scene during the twentieth century. Compromising as best we could between readability and respect for individual nations, the diagrams we present here employ the following 16 slots:

Individual countries shown are the USA, Russia[85], France, UK, Germany[86], Japan, and Israel. Hesitating to group Canada together with Central and South America, we also included it among the individual countries listed.

Regional groups of countries are:
the remaining countries of Western Europe (abbreviated as WE)[87];
the remaining countries of Eastern Europe (abbreviated as EE)[88];
the Middle East with the exception of Israel (abbreviated as ME)[89];
Central and South America (abbreviated as CSAm)[90];

[85] The meaning of this *ad hoc* term follows history. Until World War I it signifies the Russian Empire; during the existence of the Soviet Union it refers to the USSR; as of 1992 it stands for the Russian Federation. As a consequence, many Polish mathematicians for instance, such as Witold Hurewicz and Alfred Tarski, were born 'in Russia' in this technical sense.

[86] In the period 1949–1990, we use this label to refer only to the Federal Republic of Germany, grouping the German Democratic Republic with the rest of Eastern Europe.

[87] The countries of this regional group which we encounter in the biographical data of the 540 members of our population are: the four Nordic countries Norway, Sweden, Finland, Denmark; Belgium and the Netherlands; Switzerland, Austria-Hungary/Austria; Portugal, Spain, Italy, and Greece.

[88] In our biographical data we encounter the GDR, Poland, Ukraine, Czechoslovakia / The Czech Republic, Romania, and Hungary. Because of the historic variations of 'Russia' as well as Austria-Hungary/Austria, our regional group of 'Eastern Europe' makes no appearance, for instance, in the Period 1 diagrams of Figure 10.2 below.

[89] In our biographical data Iran, Turkey, Lebanon, and Saudi Arabia are mentioned.

[90] In our biographical data we find Mexico, Ecuador, Brazil, Argentina, and Chile.

India[91];
East Asia with the exception of Japan (abbreviated as EA)[92];
Australia and New Zealand (abbreviated as ANZ);
Africa.[93]

A person may have a variety of links with a country, or a part of the world. In this section we look at the worldwide distribution of the members of our population according to three different breakdowns: their *nationality at birth* (Fig. 10.2), the place where they obtained their *PhD* (Fig. 10.3), and the place of *professional affiliation* at the moment of the ICM, or ICMs, which brought them into our list (Fig. 10.4).[94]

As mentioned before, our total population is selected in a symmetric way between those that are chosen and those that choose. For instance, being chosen as a plenary speaker at an ICM qualifies a person to be in our population, just as serving on the program committee that chooses plenary speakers does. The same is true for the various other distinctions we are keeping track of. Both types of functions have to come together to craft an ICM, and its most distinguished stratum.

The plenary speakers form the biggest subgroup of our population. It turns out to be instructive—if only to avoid hasty conclusions about the relative strength of national groups in a given period—to always accompany a breakdown of our total population, given in a big annotated pie chart, by the corresponding colored chart, smaller and without annotations, for the subpopulation of the plenary speakers.

In order to see the evolution in time, the breakdowns are done separately for each of the five periods introduced above. The total numbers, relative to our whole population, of which the big charts show percentages, varies between 136 and 175 for the first four periods. It jumps up to 260 for the most recent interval 2006–2018, which comprises four ICMs like the first two periods.[95] The respective total numbers

[91] From the whole Indian subcontinent only the area of today's Republic of India occurs in biographical data of our population.

[92] In our biographical data we find China (as of 1949 the People's Republic), Taiwan, Hong Kong, Vietnam, South Korea, and Singapore.

[93] Of all African countries, South Africa is the only one that occurs in the biographical data of our population.

[94] Each person counts with multiplicity 1 for each ICM that brought him or her into our population. Given such an ICM, if a person either holds n simultaneous professional affiliations in different countries or parts of the world during that ICM, or if a person switches jobs n times between different nations or parts of the world during the year of the ICM considered, then each of the corresponding nations or parts of the world are counted with multiplicity $1/n$.

[95] More precisely, the total numbers per period underlying the various pie charts of the whole population are 175, 164, 136, 155, 260 for the charts in Fig. 10.2 and 10.4. The arithmetic mean of the first four of these numbers is 157.5. Thus the factor $\frac{260}{157.5} = 1.65$ allows us to approximately translate percentages given for the first four periods, resp. for the fifth period, into comparative sizes of the underlying groups of mathematicians. Since not every member of our population had a PhD, the underlying total numbers per period for the big charts in Fig. 10.3 are slightly different: 160, 161, 136, 154, respectively 260.

per period concerning only the plenary speakers, underlying the small charts, are as follows: 78, 68, 47, 58, 83 for the small charts in Figure 10.2 and 10.4; respectively 74, 65, 47, 57, 83 for the small charts about PhDs in Figure 10.3.

Here is an example: In Fig. 10.2 we represent our mathematicians according to the regions of the world they come from. For each one of our five periods, the corresponding part of our whole population is broken up according to regions of birth in a big chart with annotations for all parts whose size exceeds a reasonable lower bound of about 4%. Each one of these five big charts is accompanied by a small chart that uses the same colors as the corresponding big chart, but for reasons of space does not specify any percentages. For periods 1 and 2, the small chart is placed below the big chart of the periods. The small chart for period 3 figures on the right of the big annotated chart covering the interval 1983–1990. And the small charts for periods 4 and 5 are placed above their corresponding big annotated pies. These small pie charts show the breakup of all the mathematicians that gave plenary lectures at at least one of the ICMs of its period. Looking for instance at period 2, 1966–1978, we see from the small chart that the plenary speakers born either in the US or in 'Russia' account for more than half of all plenary lecturers; whereas only 20.1 + 20.1 = 40.2% of our total population for this period were born in the US or 'Russia.'

Looking at the origins of our mathematicians (Fig. 10.2), we can see the world of mathematics gradually opening up. For instance, the total share of Europe (including Russia) in our whole population shrank during the seventy years we are looking at from 77.2% in the first period to 49.2% of the population in the most recent timespan. In the charts accounting for professional affiliations (Fig. 10.4), the European share dwindles even more, from almost 59% to only about one third of the population.

East Asia on the other hand is a part of the mathematical world (in our national grouping) which advances slowly but steadily in Fig. 10.2, i.e., as a region of origin. India does as well, except for a lower presence in Period 3. A nation which makes its first appearance as a country of birth in the third period, and then establishes itself firmly, is Israel. The cupola of the ICMs is obviously much more diverse today than seventy years ago. Nonetheless, the distribution can hardly be called global, considering for instance the share of mathematicians from Africa. Indeed, Fig. 10.4 shows that not a single mathematician of our population had his or her professional affiliation in Africa, not even during the last period 2006–2018.

The motley diversity of national origins indicated in the pie charts for Period 5 of Fig. 10.2 has to be confronted with the dominating place held by the USA in the career-oriented charts. For the places where PhDs were obtained (Fig. 10.3) this US dominance starts in Period 2. In professional affiliations (Fig. 10.4) the USA clearly dominates all of the five periods. The US dominance tends to be even more pronounced within the subgroup of plenary speakers—see the small pie charts. For instance, mathematicians with a professional affiliation in the USA account for more than half of all plenary speakers in the two most recent periods.

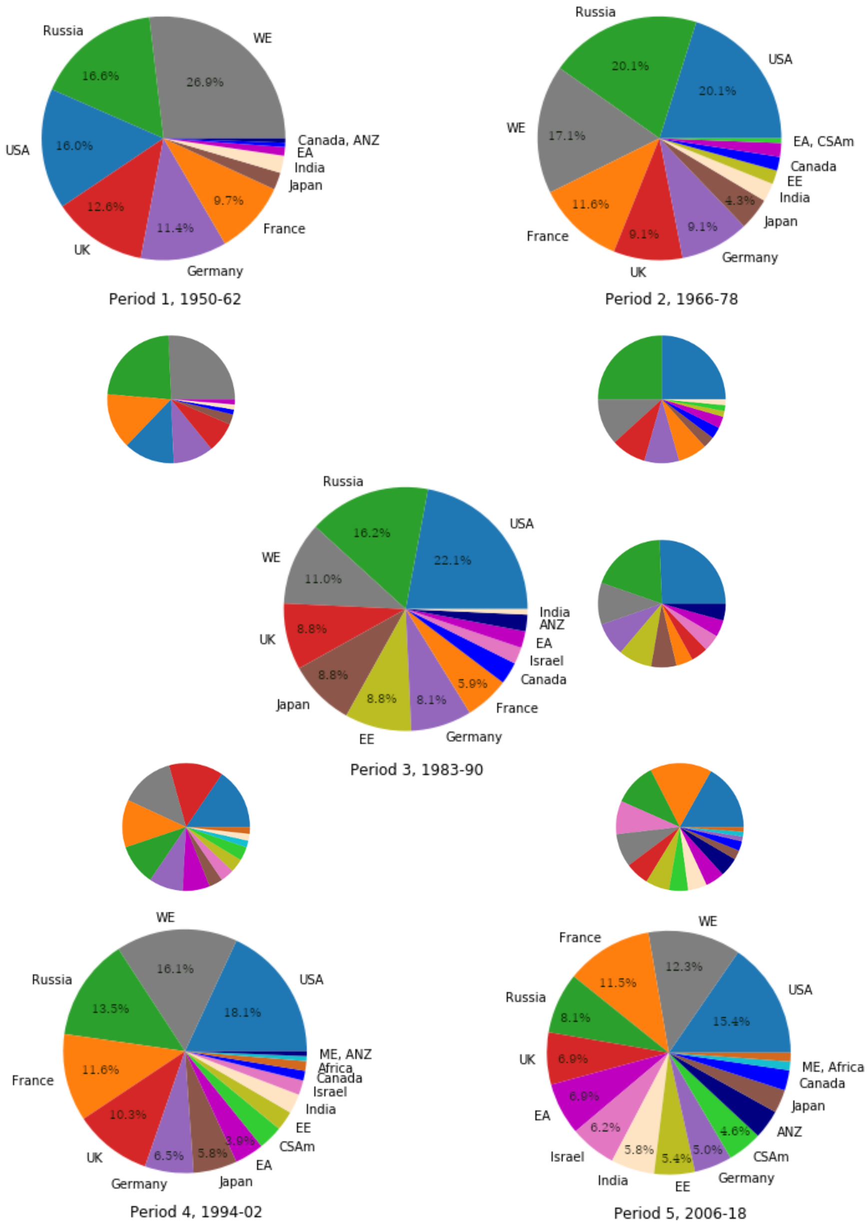

Fig. 10.2 Geographic distribution of our total population (big charts), resp. of the subpopulation of plenary speakers (small charts), according to countries of origin.

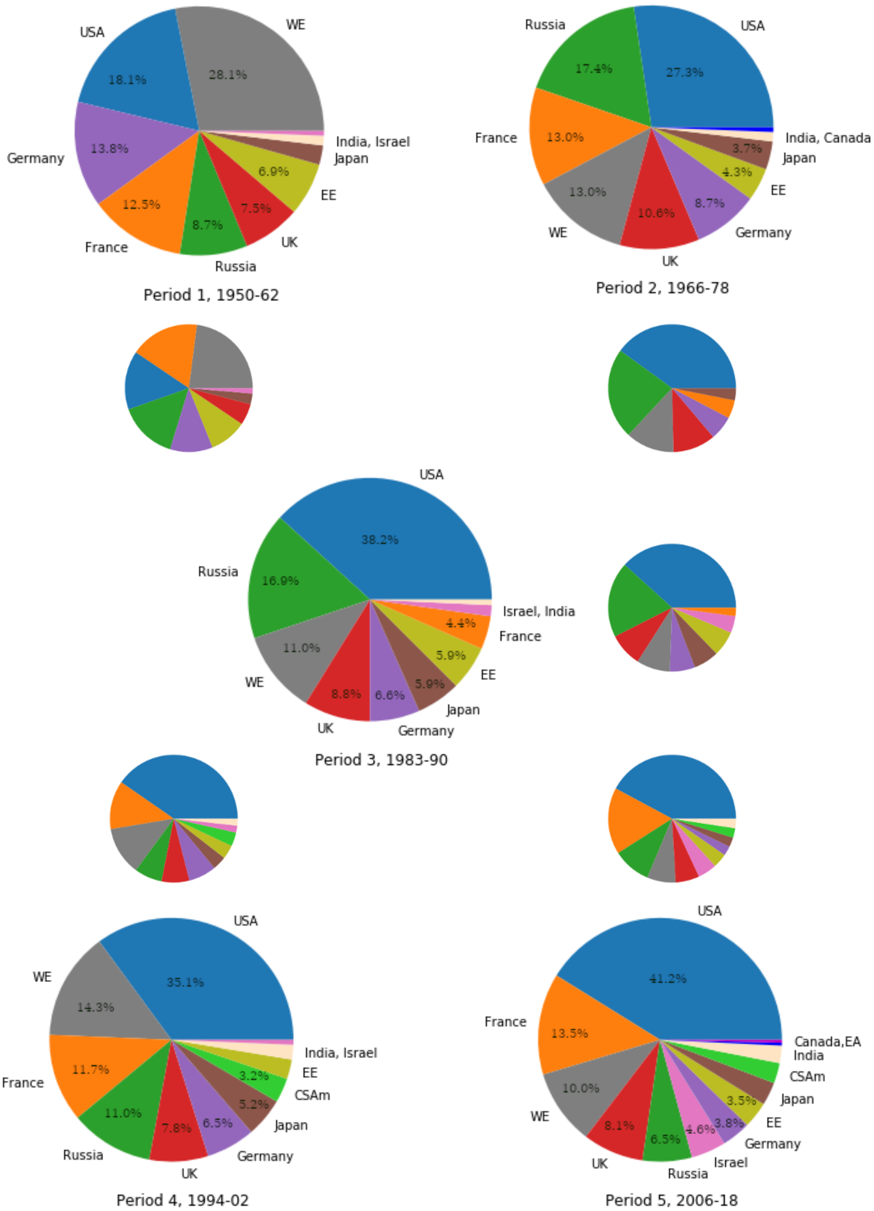

Fig. 10.3 Geographic distribution of our total population (big charts), resp. of the subpopulation of plenary speakers (small charts), according to places where their PhD was obtained.

The share of the USA as a country of origin (Fig. 10.2) grows over the first three periods, but then recedes roughly to the level of the first period. Thus the true nature of the United States for the cupola of the ICMs only comes to the fore when looking at the careers of the members of our population. Excellent careers in mathematics today have more than a 45% chance of at least passing through the US. However, the data we have are not sufficient to analyze the flow of researchers passing through the US, for instance as graduate students or young researchers, and installing themselves in permanent positions. At any rate, such a finer analysis, in order to be useful, would have to be performed on a much bigger population of mathematicians.

10.4.1.1 The Soviet Union, seen through the lens of plenary ICM lectures

As noted above, our definition of "Russia" leads to an unusually strong representation as a country of origin—including for instance mathematicians of the Polish school—in the first periods of Figure 10.2. In spite of this hitch, our data do reflect the tremendous weight of mathematics practiced in Russia, not only in Period 2, with the ICMs at Moscow and Helsinki, but also in Period 3 of Fig. 10.4. Let us look at this more closely, focussing on the subpopulation of plenary speakers.

For political reasons, the USSR was not present at the 1950 ICM at Harvard. The Soviet delegation at the 1954 ICM in Amsterdam consisted of four mathematicians three of whom gave one hour lectures: Pavel Alexandrov, Andrey Kolmogorov, and Sergey Nikolsky (1905–2012). Going through all the plenary speakers of the first period 1950–1962, and looking at their countries of birth—without assembling them into parts of the world—Russia and France lead with an equal score. Considering the plenary speakers of the first period 1950–1962 according to their countries of affiliation, the Soviet Union holds the second place, with 14.1% of all plenary speakers, and is topped only by the supremely dominating USA (44.2%).

During the second timespan, 1966–1978, the position of the USSR asserts itself strongly. Both as a country of origin and as a country of affiliation, Russia accounts for 23.5% of all plenary lectures of the second period. The number of plenary lectures given by mathematicians born in the USA outnumbered those given by Russians by just 1. And in terms of professional affiliations, the gap between the USSR and the USA observable in the first period was substantially reduced, while that between the USSR and the next smaller country France widened considerably—see the small pie charts for Periods 1 and 2 in Fig. 10.4.

The subjects addressed by Soviet plenary speakers at the ICMs of the first two periods are substantially more inclined towards applied mathematics than those of the speakers from other nations. Indeed, the invitation of colleagues from the Soviet Unions represented 15.2% of all the plenary talks of the first period; and 18% of them belonged to Mathematical Physics, a domain which appears on the whole in only 6% of all the plenary lectures.[96] In other words, 45.6% of all the plenary lectures of the first period touching on Mathematical Physics were given by Soviet mathematicians.

Similarly, in the second period, when the Soviets account for 21.5% of all the plenary lectures, 44% of all the plenary lectures touching on Optimization/Numerical Analysis/Computer Science or Algorithms were given by Soviet mathematicians.

During the third period, 1983–1990, the new official meanings of *Glasnost* and *Perestroika* entered Soviet politics. The share of the Soviet Union at the ICMs began to recede. Among the plenary lecturers of this period we find for the first time a mathematician who was born and had obtained his PhD in the USSR, but was no longer working there by the time he gave his ICM talk: Mikhail L. Gromov had left the USSR already in 1974; in the early 1980s he settled in Paris; he gave a plenary talk at the 1986 ICM in Berkeley. Nonetheless the 17% of plenary lectures given by Soviet mathematicians in the third period is still the second highest score of all countries, and it is bigger than those of Israel and France taken together—see the small chart for Period 3 in Fig. 10.4.

The decline of plenary talks given by Russian mathematicians during the last two periods reflects the brain drain of Russian mathematics during and after the end of the Soviet Union, and contributes to the process mentioned above that would offer the USA more than a 50% share of all plenary lecturers given between 1994 and 2018, according to their affiliation—see the last two small charts in Fig. 10.4. If one looks at the origins of the plenary speakers during Period 4, 1994–2002, we see 6 Russians, which puts the Russian Federation fourth among all nations, between France and Germany. But only 2 of those 6 mathematicians were still working in Russia. Two others had already obtained their PhDs abroad: the Fields Medalists Maxim L. Kontsevich (b. 1964), whose thesis director was Don Zagier (b. 1951) in Bonn, and Vladimir A. Voevodsky, who obtained his PhD at Harvard University under the direction of David Kazhdan (b. 1946).

During the most recent period, 2006–2018, Russian-born mathematicians were invited to give 9 plenary talks (approximately 11%), thus placing the country third, behind the USA and France, among the countries of origins of plenary lecturers. But only two of them were still actually based in Russia: Alexei N. Parshin, and Grigori Y. Perelman who in 2006 refused the Fields Medal and the invitation to speak. The green Russian wedge in the Period 5 charts of Fig. 10.4 has become rather slim.

If we look, not just at the plenary speakers, but at all the members of our population which had some function at one of the ICMs of the last two periods, almost precisely 40% of those colleagues who were born in the Soviet Union were still working there, whereas almost exactly 40% of them now had a job in the USA.

[96] We anticipate here the rough classification scheme into 10 major subfields of mathematics, which will be introduced in detail in Section 10.5.1 below.

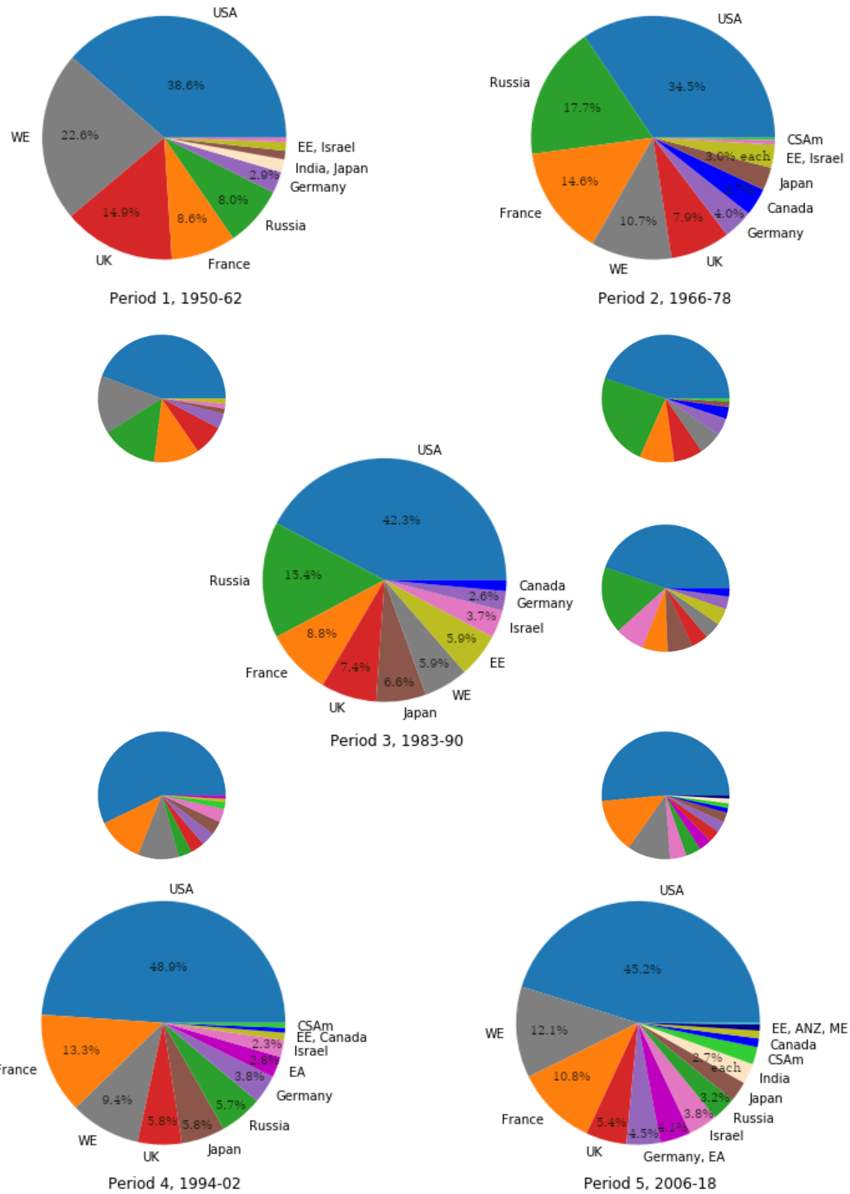

Fig. 10.4 Geographic distribution of our total population (big charts), resp. of the subpopulation of plenary speakers (small charts), according to professional affiliation.

So much about the Soviet Union. As to other individual countries, France managed to impose itself strongly after a weak spell during which fewer French mathematicians rose to the cupola. This low tide is particularly visible in the third period in Fig. 10.4.[97]

As to the other West European nations, including the UK and Germany, they did manage to reassert themselves, even though not to the point of regathering the historic weight which is still visible in the first period.

Comparing in general the big, annotated charts, which give the geographic distribution of our population as a whole—including all committee members[98]—, with the corresponding small pie charts obtained by restricting to the subpopulation of plenary speakers, we see that this crucial subpopulation tends to confirm the observations made for the whole population. However, many of the effects come out more blatantly, as we already pointed out for the US dominance in Figure 10.4. The sagging and subsequent comeback of France starts earlier and is more marked in the small charts of Figure 10.3.

10.4.1.2 The Program Committees

The plenary speakers at an ICM were selected by the Program Committees (PC).[99] Their altogether 182 members—of whom 13 have served twice, in Program Committees at two different ICMs—are part of our population. We can thus look at their geographic breakdown according to origin or affiliation.

Since we have already analyzed the plenary speakers, and since 93 of the 195 seats on the Program Committees were held by colleagues who were also plenary speakers at some ICM,[100] it makes sense to restrict to the 102 committee members who were never invited as plenary lecturers, between 1950 and 2018. Among these colleagues we tend to find in particular the PC members who were appointed by the local Organizing Committee of the corresponding ICM.

The geographical distribution according to professional affiliations of those PC members who were not plenary speakers is noticeably different from what we have seen in Fig. 10.4. Not surprisingly, it tends to be strongly influenced by the places where the ICMs were held. Thus in the first period, with its ICMs at Cambridge (Mass.), Amsterdam, Edinburgh, and Stockholm, the four countries USA, the Netherlands, UK, and Sweden, account for more than 94% of the members of PCs who were

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[97] For an overview of the situation in France, see [Menger et al. 2020]. Cf. the *Rapport national de conjoncture scientifique 1969* commissioned by the CNRS, which was prepared by several leading French mathematicians with a view to improving the situation of mathematical research in France.

[98] . . . and also the prize winners; but their statistical effect is relatively small.

[99] Cf. Section 10.2 above for the gradual evolution over time, its composition and its name, of what is known today as the ICM Program Committee.

[100] There are seven cases where a member of the PC also gave a plenary lecture *at the same ICM*. The last time this happened was in 2002 at Beijing. The typical case is of course a plenary speaker who will be recruited for the PC at a later ICM. Note that our data do not record any information about plenary lectures given at ICMs before World War II.

never plenary speakers. Similarly, in the second period, the Soviet Union, France, Canada, and Finland represent 76.4%. In Period 3, Poland, the USA, and Japan account for 70%; adding to this the Soviet Union covers 90% of all PC members of the third period. The effect is much less pronounced in the last two periods, with a share of 40.2%, respectively 52%, of members employed in one of the countries where an ICM of the corresponding period was held. But here too, between 1994 and 2018, the geographical breakdown of the professional affiliations of PC members who never were plenary speakers looks very different from what we see in Fig. 10.4. For instance, the USA only has a share of 13.6% in Period 4, and 10% in Period 5.

10.4.2 Institutions of the Cupola

Having looked at the way in which countries, respectively parts of the world, contributed to the Cupola of the ICMs, let us now try and scale down our attention to individual academic institutions. To be chosen as a plenary speaker for an ICM conveys considerable prestige to a mathematician. It is the sort of distinction that affords a bright mention in a CV. In the world of the ICMs it is topped only by the public celebrity that comes with a Fields Medal, or maybe a Nevanlinna Prize.[101] Relative to a given ICM, we introduce the initialism *FNP* to refer to all those persons who were awarded a Fields Medal, received a Nevanlinna Prize, or were invited to be a Plenary Speaker at that ICM. Having one of its members chosen as FNP at an ICM consolidates an academic institution's standing in the world of mathematics, and inviting or recruiting such a mathematician is in their best interests.

The set of all the mathematical institutes that were home to an FNP is too big and variegated to be conveniently surveyed and followed through the five periods. Therefore we try to single out mathematical institutions that had a notable share of FNP colleagues. For each period we will thus determine a set of research-oriented mathematical institutes whose recruitment politics and research agenda accommodated particularly well the mathematical excellence framed by the ICMs, and by the IMU, for the corresponding timespan.

After testing several variants, we finally settled on the *ad hoc* approach described below, which proved to be adapted to the purpose. It turns out to account for more than half of the FNPs in all our five time periods. The nitty-gritty details of the analysis do not make for a particularly pleasant read. The reader may skip them and go straight away to the subsequent discussion of the five periods, where we also mention a few of the names behind the institutes that occur.

[101] We do not consider the Gauss Prize in this section, because this would have a potential bearing only on the last of our five periods. The Nevanlinna Prize was awarded during the last three periods.

Technicalities. Let us fix one of our five periods.[102] We then pose the following

Definition. An academic institution employing mathematicians is called an *Institution of the Cupola* relative to this period—or a *CI* for short—if at least one of the following two conditions is satisfied:

- There exists at least one ICM of this period at which at least two mathematicians affiliated with the institution were chosen as FNPs;
- at most one ICM of the period has not seen any FNP from among the mathematicians affiliated with the institution.[103]

In order for this definition to be effective, we have to make precise how we count (i) institutions, and (ii) mathematicians from the FNP group.

(i) When checking the conditions of the definition, in most cases it is obvious which institutions need to be considered. Clearly mathematical institutes of universities should qualify just as well as LGTRSs.

There are two subtle cases, which we solve by inclusion: The first problem we have encountered in mustering the affiliations of all the FNP colleagues concerns the University, or the Universities of Paris. Indeed, until the 1960s there was a unique *Université de Paris*, which also included the *Ecole Normale Supérieure* (ENS) as one of its components. It was then split up into thirteen individual universities in 1970 as part of the political reaction to the student revolt of May 1968. In recent years, regrouping universities has again gained ground in France. For the sake of coherence over the seventy years studied here, in the present section we have decided to lump together all Paris universities, including the Paris branch of the ENS, into one 'institution' for all of our five periods. We shall call this synthesis *Paris, University*.

The second place that calls for explanation is Moscow, more precisely the relationship between Lomonosov State University and the Academy of Sciences at Moscow. Simultaneous affiliations with both institutions were very common; about half of the FNPs at Moscow State University were also linked to the Academy. Furthermore, both Moscow State University and the Academy at Moscow qualify individually as CIs during our first two periods. Moscow State University also qualifies as a CI by itself for the third period.[104] Considering their large intersection, we treat the union of both institutions as a single CI, which we call *Moscow State University & Academy of Sciences*, or *Moscow U&A* for short. This does not include other institutions in

[102] Our analysis in this section proceeds period by period. Looking at other time intervals would conceivably yield slightly different lists of distinguished institutions. Indeed, our goal is by no means to establish a ranking of institutional excellence. We simply continue to spell out the image of mathematics projected by the sequence of ICMs, and how it highlights certain institutes.

[103] To render this second condition coherent over time, we artificially adjust our five periods so that all of them contain four ICMs. Therefore, whenever we check the second condition, we keep the 1978 ICM in Helsinki in Period 2, but we also count it for Period 3; and likewise we include the 1990 ICM in Kyoto both in Period 3 and in Period 4 when checking this second condition.

[104] To verify this, one has to apply the second condition of CIs, adding the Helsinki ICM as explained in the previous footnote.

Moscow—see for instance the occurrence of the Moscow Institute for Information Transmission (IPPI) in Period 2.

(ii) Here is how we count the FNPs of a given period. When looking at one ICM of the period we just count heads. That is to say, for instance, that a person who receives a Fields Medal and also gives a plenary lecture at the same ICM is counted as one FNP. However, going through the 3 or 4 ICMs of a given period, a mathematician may be selected as an FNP at several of them, say at m of the ICMs ($1 \leq m \leq 4$). It turns out that $m \leq 2$ for all members of our population and for every period selected.[105] For the whole period, each FNP person will be counted with its multiplicity m.

It would theoretically be possible that our definition establishes an institution as a CI, for a given period, due to a single FNP mathematician, who received such an honour at several ICMs of the period. This might be considered awkward. As a matter of fact, such a case never presents itself in any of our five periods.

Finally, a mathematician who is chosen as an FNP at an ICM may be affiliated during the year of that ICM with more than one institution. Indeed, there are cases where an FNP is affiliated, during the year of the ICM in question, with two different CIs of the corresponding period. (Such a circumstance does not affect the verification of either of the criteria of our definition from the point of view of any of the institutions to which the person is bound.) These cases, however, are not frequent enough to warrant a detailed investigation.

Let us now walk through the five periods and see in each of them which institutions distinguish themselves with respect to the ICMs of that period. A hard core of CIs based in the USA will emerge throughout the seventy year span. We shall briefly comment on them at the end of this section. Other interesting CIs will be discussed as we go along.

Period 1, 1950–1962. For the first period, we find ten Institutions of the Cupola, i.e., ten CIs. We list them here in descending order according to the number of FNPs of Period 1 affiliated with the establishment in question.

- Moscow State University & Academy of Sciences
- The Institute for Advanced Study, Princeton
- Princeton University
- Paris, University
- University of Chicago
- Columbia University
- The Swiss Federal Institute of Technology, ETH, Zürich
- Harvard University
- Massachusetts Institute of Technology, MIT
- University of California at Berkeley, UCB.

[105] Several mathematicians have been chosen as FNPs at three different ICMs in the course of their career, but never within one of our periods.

Altogether we count[106] for the first period 49 FNPs affiliated to these ten CIs.[107] This amounts to almost 60% of altogether 82 FNPs[108] in Period 1.

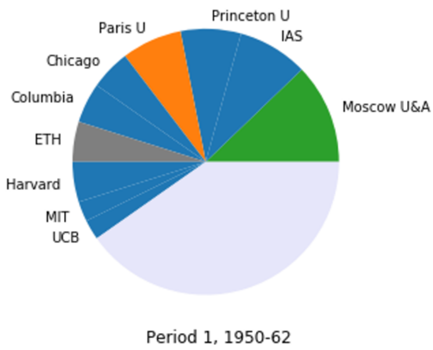

Fig. 10.5 The FNP share of CIs during Period 1; colors correspond to the countries of the institutions.

Note the strong presence of Moscow U&A in spite of the fact that the first ICM of the period, in 1950, took place without any Russian participation.

The ETH in Zürich qualifies as a CI in this period on account of both conditions of our definition, thanks to plenary lectures given by Heinz Hopf in 1950, Eduard Stiefel (1909–1978) at the 1954 ICM, and by Beno Eckmann (1917–2008) and Peter Henrici (1923–1987) at the 1962 ICM. In fact, 1962 was also the year when Henrici moved from UCLA to Zürich; but UCLA does not qualify as a CI for the first period.

Period 2, 1966–1978. Thirteen CIs are borne out by the four ICMs between 1966 and 1978. Here they are, again in descending order of the number of FNPs affiliated with these institutes.

- Moscow State University & Academy of Sciences
- Princeton University
- Harvard University
- Massachusetts Institute of Technology, MIT
- *Institut des Hautes Études Scientifiques*, IHES, Bures-sur-Yvette (near Paris).
- University of California at Berkeley, UCB
- The Institute for Advanced Study, Princeton
- University of Chicago
- Stanford University
- Paris, University

[106] In the sense explained above: a person chosen as FNP at m distinct ICMs of the period is counted with multiplicity m.

[107] The number of individual persons giving rise to these 49 FNPs is 44.

[108] Corresponding to 76 physical persons.

- *Institut problem peredachi informatsii* (Institute for Problems in Information Transmission), IPPI, Moscow
- *Collège de France*, Paris
- University of Cambridge, UK

We count, with multiplicities as before, 53 FNPs linked to these thirteen CIs of the second period. This represents almost 68% of the 78 FNP total of Period 2.[109]

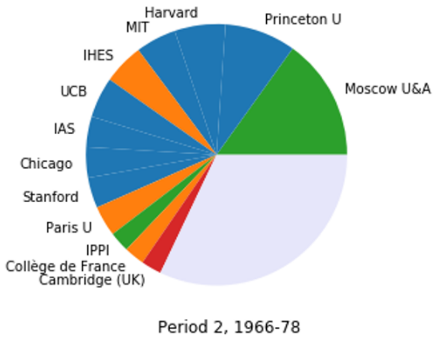

Fig. 10.6 The FNP share of CIs during Period 2.

IHES was founded in 1958—cf. Section 8.3 above. It makes its first appearance as a CI in this list for the second period, thanks to Alexander Grothendieck's 1966 Fields Medal (*in absentia*), Pierre Deligne's plenary lecture in 1974 as well as his 1978 Fields Medal, and Dennis Sullivan's (b. 1941) plenary lecture in 1974 at Vancouver.

The *Collège de France* happens to meet the first condition of a CI in this second period because two of the plenary speakers at the 1974 ICM in Vancouver held chairs at this venerable French institution (founded in 1530, open to the French public and independent of the French system of higher education): Jacques-Louis Lions and Jacques Tits (1930–2021).

The IPPI at Moscow owes its presence in our list, next to the Moscow U&A, to Grigory A. Margulis, who was awarded the Fields Medal in 1978, and to Roland Lvovich Dobrushin (1929–1995), who gave a plenary lecture at the 1978 ICM in Helsinki.

At the 1970 ICM in Nice, France, it happened for the first time that two out of four Fields Medals were awarded to mathematicians from the University of Cambridge, UK. The same constellation would repeat itself at the Berlin ICM in 1998, in Period 4. Periods 2 and 4 are the only ones where Cambridge University rose to CI status. In 1970 the two winners of the Fields Medal were Alan Baker (1939–2018) and John G. Thompson (b. 1932). In fact, Thompson only moved to Cambridge in 1970 where

[109] The count involves 48 physical persons affiliated with a CI, i.e., more than three quarters of the altogether 63 mathematicians chosen for FNPs during the second period.

he was offered the Rouse Ball Professorship. He had already given a plenary lecture on the classification of finite simple groups in Moscow in 1966, when he was still at the University of Chicago, another CI of the second period.

Period 3, 1983–1990. We find twelve CIs for this period of only three ICMs. They are listed hereafter in descending order of the number of FNPs affiliated with them. For the first time, institutions from outside of the USA and Europe make their way into the list, in this period that saw the very first ICM held neither in Europe, nor in North America: in Kyoto, Japan, in 1990.

- Princeton University
- Harvard University
- *Institut des Hautes Études Scientifiques*, IHES, Bures-sur-Yvette (near Paris).
- Massachusetts Institute of Technology, MIT
- University of California at Berkeley, UCB
- Research Institute for Mathematical Sciences, RIMS, at Kyoto
- The Hebrew University, Jerusalem
- Moscow State University & Academy of Sciences
- Courant Institute, New York University, NYU
- Brown University,
- University of California at San Diego, UCSD
- The Institute for Advanced Study, Princeton.

We count, with multiplicities as before, 36 FNPs affiliated with one of these twelve CIs of the third period. This represents about 64% of the 56 FNP total of Period 3.[110] Note that the third period is the first one that comprises only three ICMs.

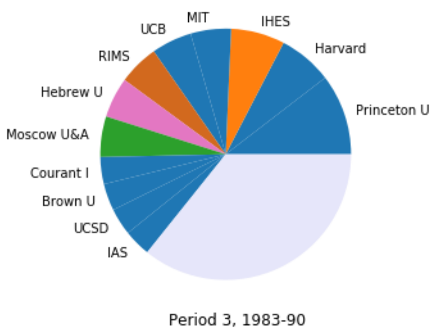

Fig. 10.7 The FNP share of CIs during Period 3.

[110] The count involves 34 physical persons affiliated with the CIs, out of the altogether 54 mathematicians chosen for FNPs during the third period.

The Hebrew University at Jerusalem makes its first appearance as a CI in period 3, in view of the plenary lectures given by Michael O. Rabin (b. 1931) in Warsaw in 1983, and the fact that Saharon Shelah was invited for a plenary talk at the same ICM. Shelah did not attend the Warsaw Congress, though, but was invited again and gave a plenary talk in 1986 at Berkeley.

The RIMS in Kyoto enters the above list of CIs for the third period on several accounts. To start with the 1990 ICM, which brought the mathematical world to Kyoto and which closes this period, Shigefumi Mori was awarded the Fields Medal, and Yasutaka Ihara (b. 1938) gave a plenary lecture. This already checks the first condition of our definition of a CI for the third period.

Furthermore, Mikio Sato (b. 1928) presented a plenary lecture at the Warsaw ICM in 1983, and Masaki Kashiwara (b. 1947) had given a plenary talk at Helsinki in 1978 (which enters into the verification of the second condition of our definition of a CI for the third period, even though it belongs to period 2). Thus RIMS also satisfies the second condition of a CI for Period 3.

Michael H. Freedman's (b. 1951) Fields Medal in 1986 was one of the two events that brought the University of California at San Diego into our list for Period 3. The other one is Richard M. Schoen's (b. 1950) plenary lecture at the Berkeley ICM in 1986.

New York University owes its place in the period to Robert Tarjan's (b. 1948) Nevanlinna Prize and Peter Lax's (b. 1926) plenary address in 1983.

Brown University is listed in view of the 1983 plenary talks presented by Wendell H. Fleming (b. 1928) and Robert MacPherson (b. 1944).

Period 4, 1994–2002. In this second period consisting of only 3 ICMs, we find the following ten CIs, ordered as before.

- Paris, University
- Massachusetts Institute of Technology, MIT
- Princeton University
- Harvard University
- University of California at Berkeley, UCB
- Stanford University
- The Institute for Advanced Study, Princeton
- *Institut des Hautes Études Scientifiques*, IHES, Bures-sur-Yvette (near Paris).
- University of Chicago
- University of Cambridge, UK

For this fourth period, we count—with multiplicities, as before—41 FNPs affiliated with (at least) one of the ten CIs. This represents about 62% of the 66 FNP total of the penultimate period.[111]

[111] The count involves 39 physical persons affiliated with the CIs, out of the altogether 64 mathematicians chosen for FNPs during the fourth period.

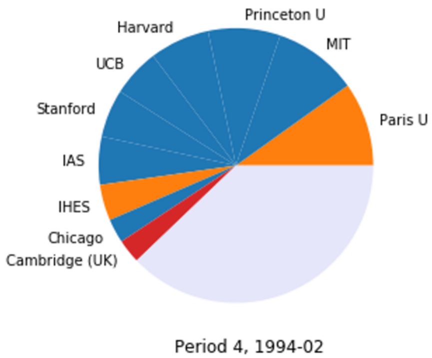

Fig. 10.8 The FNP share of CIs during Period 4.

We have already mentioned above the double score of Cambridge University for the Fields Medals awarded at Berlin in 1998: Timothy Gowers and Richard Borcherds (b. 1959).

Note that Moscow State University & Academy has disappeared from the list of CIs in Period 4, after the end of the Soviet Union. Already in the third period, Moscow U&A barely passed the criterion of a CI. This fact is related to a gradual redistribution among institutions. In the first period, 86.4% of the Soviet FNPs were affiliated with Moscow U&A. During the second period, 14 out of 18 FNPs from the USSR were employed in Moscow; 12 of them were affiliated with Moscow U&A. Our short third period sees 7 out of 11 Soviet FNPs employed in Moscow, but only 3 affiliated with Moscow U&A.

Seven of the ten CIs of Period 4 are based in the USA, and the fourth period is the only one in which all CIs are based in only three different countries: the USA, France, and the UK. This may have to do with the fact that the period only comprises three ICMs. At any rate, it does not indicate a trend towards national concentration, as is shown by the subsequent period:

Period 5, 2006–2018. For this most recent period, we find fifteen CIs, listed as before in descending order of their FNP count.

- Paris, University
- Princeton University
- University of California at Berkeley, UCB
- Stanford University
- Yale University
- Courant Institute, New York University, NYU
- Massachusetts Institute of Technology, MIT
- The Hebrew University, Jerusalem

- The Institute for Advanced Study, Princeton
- University of Chicago
- *Instituto Nacional de Matemática Pura e Aplicada*, IMPA, Rio de Janeiro
- The Swiss Federal Institute of Technology, ETH, Zürich
- University of California at Los Angeles, UCLA
- University of Oxford, UK
- The Hausdorff Center of Mathematics, HCM, Bonn, Germany.

For this last period, which comprises four ICMs, we count—with multiplicities, as before—58 FNPs affiliated with (at least) one of the 15 CIs. This amounts to about 60% of the 96 FNP total of the period.[112]

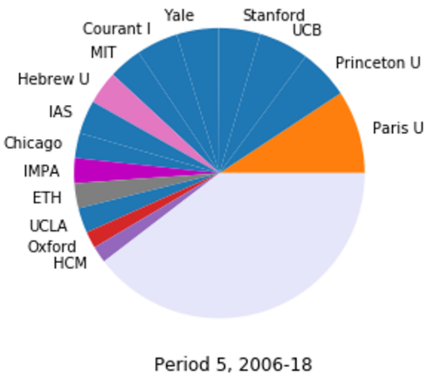

Fig. 10.9 The FNP share of CIs during Period 5.

This most recent period displays the biggest number and the greatest diversity of CIs. The presence of the Courant Institute, New York, marks a kind of opening towards more applied mathematics. Its strong presence among the CIs of Period 5 is afforded by various events, which took place at three different ICMs: Subhash Khot's (b. 1978) Nevanlinna Prize in 2014; the 2006 plenary lectures by Percy Deift (b. 1945) and Robert V. Kohn (b. 1953); finally the 2018 plenary talks by Sylvia Serfaty (b. 1975) and Lai-Sang Young (b. 1952).

The IMPA in Rio de Janeiro makes its appearance among the ICs of the last period, not because of the Rio ICM in 2018, but because of Artur Avila (b. 1979), who was awarded the Fields Medal in Seoul in 2014—he had already presented a plenary lecture in Hyderabad in 2010—, and Fernando Marques's (b. 1979) plenary lecture in Seoul.

The example of the Swiss ETH is interesting because none of its three FNP members during the fifth period is of Swiss origin. Two of them, the Greek mathematical physicist Demetrios Christodoulou (b. 1951) and Rahul Pandharibande (b. 1969), of

[112] The count involves 57 physical persons affiliated with the CIs, out of the altogether 94 mathematicians chosen for FNPs during the fifth period.

Indian origin, started their careers in the US and had been professors at Princeton University—one of our perennial CIs—before coming to Zürich. They gave plenary lectures in 2014, resp. 2018. The 2018 Fields Medalist Alessio Figalli (b. 1984) grew up in Italy and received most of his advanced research training in France. In 2016, he moved to the ETH.

Peter Scholze's Fields Medal in 2018 would not have sufficed to make the Hausdorff Center at Bonn a CI for the fifth period. The other person needed for that was Geordie Williamson (b. 1981) from the University of Sydney. After his earlier stay at the Max-Planck-Institute for Mathematics at Bonn, Williamson was still a Bonn Research Fellow in 2018.

These two CIs of the fifth period, ETH and HCM, remind us of the intrinsically international mathematical culture that is generally implemented today at all major research centers, not only at the institutions we are looking at here. This is usually taken for granted, even though it is the result of a fairly recent historical process—see Sections 5.2 and 8.3 above. All these research-oriented institutes are of course locally based in their respective countries. For our small selection this is shown by the colors of their pieces in the pie charts. Not all countries can pride themselves of such institutes, let alone of CIs that make it into our selection. However, all major existing research centers cultivate their international dimension, often with an almost global reach. Focussing again on the CIs, this twofold reflection of today's global academic world: in the colors of the charts, and in the origins of individual researchers, was particularly pronounced in the latest period. It holds the promise of a continuing worldwide mathematical network for the future.

Surveying all five periods, we find exactly four institutions that turned out to be CIs in every single period: the Institute for Advanced Study as well as Princeton University, the University of California at Berkeley, and the Massachusetts Institute of Technology MIT. All of them are located in the USA, and each of them is a visible competitor for outstanding mathematical talent on the global market. Altogether, over all the five periods, these four institutions have been the home base of 90 FNPs. This is not far from a quarter of the 378 FNPs of all periods. (About two thirds of this total count of 378 FNPs—249 of them, to be precise—were affiliated with some CI of their respective period.)

Three other institutions are CIs in all but one time period: the Universities of Chicago, Harvard, and Paris, University.

Two further institutions managed to rise to the cupola in three consecutive periods: Moscow U&A in the first three periods, and IHES (which was founded only in 1958) in periods 2 through 4.

Stanford University also appears three times, if not in consecutive periods.

Whereas French institutions are certainly visible in the first three periods, the conglomerate of the Paris Universities turns out to be the biggest CI worldwide in the two most recent periods 4 and 5. Even more is true: In Period 4, IHES is also a CI; its FNPs for that period were all Fields Medalists: Jean Bourgain (1954–2018) in 1994, Kontsevich in 1998, and Laurent Lafforgue in 2002. Let us for a moment amalgamate Paris University and IHES.[113] Then it turns out that, both in Period 4 and in Period 5, this combined institution counts precisely as many—namely, ten—FNPs as were located at Princeton (taking IAS and Princeton University together), during each of the last two periods.

France is a particularly centralized country, and what we call "Paris University" is a synthesis of all Paris universities. This may partly explain the extraordinary performance of this CI since 1994. Nevertheless, already the sheer list of mathematicians professionally affiliated with Paris when they received their Fields Medal in those years—apart from the three mentioned above, there were Pierre-Louis Lions (b. 1956) and Jean-Christophe Yoccoz (1957–2016) in 1994, Wendelin Werner (b. 1968) in 2006, Cédric Villani (b. 1973) in 2010, and Artur Avila in 2014—establishes Paris as the mathematical hotspot that has resonated most intensely with the Cupola of the ICMs during the last quarter century.

Traces of Mathematical Genealogies in the Cupola. We have investigated all the members of our population whose thesis advisors are also in the database. The resulting *PhD graph* of advisorships inside of our population has 68 connected components, 38 of which are just couples. The idea of a PhD thesis has changed according to historical and national contexts, and the type of relationship between thesis student and advisor depends on local cultures as well as personal idiosyncrasies. Yet, even if there are also other influences in mathematical careers than those exerted by advising a thesis, the PhD graph does illustrate a basic transmission of academic mathematical excellence inside our population. This justifies showing a few remarkable connected components.

By far the biggest connected component of our PhD graph is that formed by Kolmogorov's thesis students who would themselves enter our population at a certain point in time—see Fig. 10.10. In fact, only about 1/8 of all of Kolmogorov's thesis students belong to our database. Here and in the following graphs each dot in our diagrams represents a person from our population. The persons that show up in this component, besides Andrey Kolmogorov, are Anatoli Vitushkin, Israel Gelfand, Sergey Nikolsky, Anatoly Maltsev (1909–1967), Roland Dobrushin, Albert N. Shiryaev (b. 1934), Yuri Prokhorov, Yuri Rosanov (b. 1934), Yakov Sinai (b. 1935), Eugene Dynkin, and Vladimir Arnold. The following 'generations' include Alexander Varchenko (b. 1949), Victor Vassiliev (b. 1956), Anatoliy Skrokhod (1930–2011), Grigory Margulis, and Marina Ratner (1938–2017). The only person in this component who did not get her degree at Moscow University is the South Korean mathematician Hee Oh (b. 1969), who obtained her PhD at Yale University in 1997 under the direction of Margulis.

[113] For Period 5, it is enough to only consider Paris University, since IHES did not have a single FNP during those years.

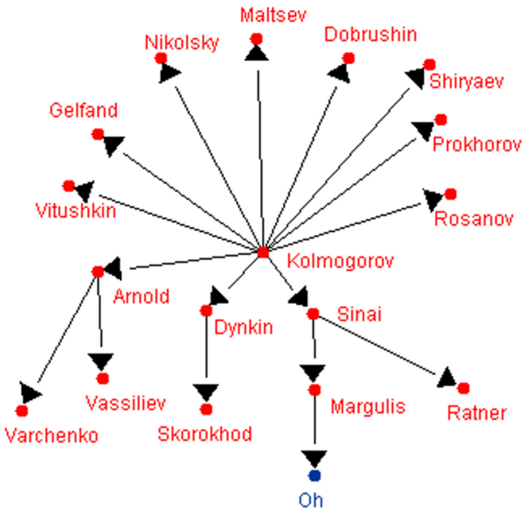

Fig. 10.10 Kolmogorov's component of the PhD graph in our population.

In Fig. 10.11 we present all the other connected components of the PhD graph within our population that have at least six vertices. The most frequent nationality in each component is shown in red; the blue vertices correspond to nation origins different from the dominant one.

The page starts with Shokichi Iyanaga's component, which is completely situated in Japan. It comprises Kenkichi Iwasawa, Kiyoshi Ito (1915–2008), Mikio Sato, Yasutaka Ihara; and from there to Michio Jimbo (b. 1951), Masaki Kashiwara, Tetsuji Miwa (b. 1949), and to Ihara's student Kazuya Kato (b. 1952).

To the right, we start from Laurent Schwartz, who leads us to Alexander Grothendieck, Gilles Pisier (b. 1950), Bernard Malgrange (b. 1928), Jacques-Louis Lions, Michel Raynaud (1938–2018), Pierre Deligne, Jean-Michel Bismut (b. 1948); and via Deligne to Michael Rapoport (b. 1948) and Peter Scholze.

William Hodge's progeny includes Michael Atiyah, Simon Donaldson (b. 1957), George Lusztig (b. 1946), Frances Kirwan (b. 1959), Peter Kronheimer (b. 19639), and Corrado de Concini (b. 1949).

Another genealogy starts in the UK with Harold Davenport. It includes Alan Baker, Hugh L. Montgomery (b. 1944), John Conway (1937–2020), and Richard Borcherds. From Baker we get to John Coates (b. 1945), whence Catherine Goldstein (b. 1958), as well as the branch of Andrew Wiles (b. 1953), with Richard Taylor, and Manjul Bhargava (b. 1974).

Heinz Hopf leads us to Hans Freudenthal—who got his PhD when Hopf was still in Berlin. Later in Zürich he was one of the thesis advisors of Friedrich Hirzebruch, even though the latter obtained his degree in Münster, Germany with Heinrich

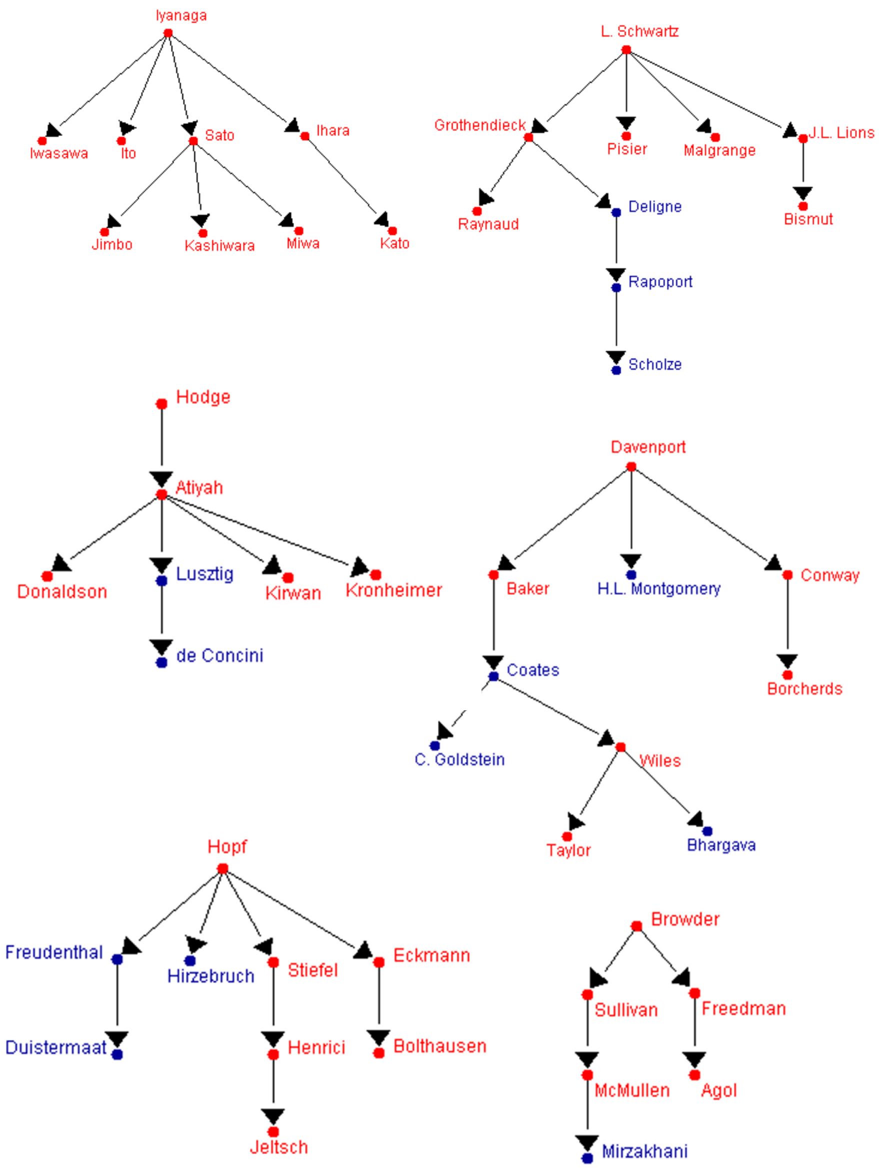

Fig. 10.11 Various components of the PhD graph in our population.

Behnke. Further there are Eduard Stiefel and Beno Eckmann. From there we pass to Johannes Duistermaat (1942–2010), Peter Henrici, Erwin Bolthausen (b. 1945), and finally to Rolf Jeltsch (b. 1945).

We conclude the samples in Fig. 10.11 with a graph situated in the USA, starting from William Browder (b. 1934): Dennis Sullivan, Michael Freedman (b. 1951), Curtis McMullen (b. 1958), Ian Agol (b. 1970); and Maryam Mirzakhani.

10.5 Framing Domains of Mathematics

Mathematicians enter our database because their mathematical creativity or expertise is recognized as outstanding or particularly useful for a successful ICM. In the preceding section we have tried to portray this group of people geographically according to their origins and professional affiliations. The present section addresses their mathematical specialties. Since we are dealing with the cupola of the ICMs, the breakdown of the domains of expertise upheld by our population, and its evolution over time, reflects the domains of mathematical research that received particular attention on the part of the framers of the ICMs.

10.5.1 Mathematical Subdomains

In order to screen for mathematical specialties we shall use the following rough breakup of mathematics into major subdomains.[114] Note the corresponding abbreviations that will be used for quick reference in the sequel.

- **Gen**: General Mathematics; History; Foundations. This corresponds to sections 00, 01, 03, 06, 08, and 18 of the Mathematics Subject Classification MSC.[115]
- **Discr**: Discrete Mathematics & Convex Geometry; MSC sections 05, 52.
- **NTAG**: Number Theory. Algebra. Algebraic Geometry. Group theory; MSC sections 11, 12, 13, 14, 15, 16, 17, 19, 20.
- **Ana**: Real and Complex Analysis; MSC sections 26, 28, 30, 31, 32, 33, 40, 41.
- **OpTh**: Harmonic and Functional Analysis; Operator Theory; MSC sections 42, 43, 44, 46, 47.
- **DIEq**: Differential and Integral equations; MSC sections 34, 35, 37, 39, 45.
- **OptCS**: Optimization. Numerical Analysis. Computer Science. Algorithms; MSC sections 49, 65, 68, 90, 93, 94.
- **ProbStat**: Probability Theory and Statistics. Applications to Economics, Biology and Medicine; MSC sections 60, 62, 91, 92.
- **TopGeo**: Topology and Geometry; MSC sections 22, 51, 53, 54, 57, 58.
- **MaPh**: Mathematical Physics; MSC sections 70, 74, 76, 78, 80, 81, and 82.

[114] It has been used in a similar manner before, for instance in [Mihaljević & Teschke 2014].

[115] As mentioned before, he relevant websites are [URL 59] jointly with [URL 60], and [URL 61]. This classification has been systematically used by zbMATH Open since 1980.

In order to be able to appreciate how our cupola differs from the overall mainstream of mathematical production, let us start with the total distribution of the almost 3.6 million publications refereed in the *Zentralblatt*—or rather zbMATH Open, as it is now called—between 1949 and 2020; their breakup is shown in Fig. 10.12.[116] The four leading domains—each of which represents more than 10% of the total—are Optimization (including Computer Science), Mathematical Physics, Probability and Statistics, and Differential & Integral Equations. Even though it gives a first impression of the mathematical production per domain, this pie chart can also be misleading, if only because publication strategies vary from one mathematical speciality to another. Some may, for example, tend to prefer a greater number of shorter pieces in specialized journals to a smaller number of major papers in highly visible periodicals.[117] We nonetheless use this chart as a signpost of the mathematical production at large.

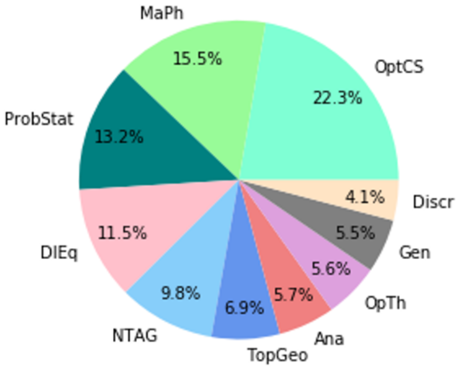

Fig. 10.12 The distribution of all publications refereed in zbMATH Open between 1949 and 2020.

[116] Here and in the sequel of this section we profit from the generous massive access to zbMATH Open data as well as additional information, which was granted us for the preparation of this book. Personal thanks go to Olaf Teschke for being such a reliable partner in this collaboration. As of 2021, the major part of these data are available via the API [URL 62] under CC-BY-SA 4.0 license. This should make it possible to reproduce the analyses presented here, or to perform similar ones.

[117] The classification used by *Zentralblatt*, resp. zbMATH Open, has also evolved over time. However, all older papers classified in a way that is no longer used today can be sorted unambiguously with respect to our ten subdomains. As for multiple classifications, which do occur frequently, if a paper is classified to belong to n different subdomains of our list, each of these subdomains is counted for that paper with weight $1/n$.

10.5.2 Fields Medalists

One of the first ideas one may have, if one wants to compare Fig. 10.12 to the Cupola of the ICMs, is to look at the sequence of Fields Medal, and how the work for which they have been awarded is distributed among our ten subdomains of mathematics. Indeed, no other distinction in the domain of mathematics catches the public eye as much as the Fields Medal.[118] An oft-heard comment points out that the choice of the Fields Medals expresses a strongly biased image of the broad advance of the mathematical sciences, highlighting certain areas of pure mathematics disproportionally.

> All 56 winners [of the Fields Medal] so far have been phenomenal mathematicians, but such biases have contributed to 55 of them being male, most being from the United States and Europe and most working on a collection of research topics that are arguably unrepresentative of the discipline as a whole.[119]

Some such information about the Fields Medals can indeed be seen immediately in our data. For instance, about two thirds of all Fields Medalists have worked in the domains *NTAG* or *TopGeo*.[120] Still, we abandoned this sort of inquiry after a few initial attempts. The principal reason is that the sample is too small to allow for an enlightening study of distributions. This continues to hold true when one tries to enlarge the group studied by adding the Fields Medal Committee members. Independently of the method one would like to apply, it should also be remembered that in most cases the actual Fields Medalist had to be chosen from among a small group of comparable contenders.[121]

Given all these difficulties, we think that the serious study of the attribution of Fields Medals over the years has to wait until the archival evidence concerning the work of the Fields Medal Committees is accessible for historical scrutiny. Unfortunately, in view of the extravagant 70-year embargo imposed by the IMU on the files of all of its Prize Committees, this means that we still have to wait quite a long time. This renders occasional insights gleaned from other, accessible sources, as in Barany’s work, all the more exciting.

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[118] The comparison of the Fields Medal with the Nobel Prize sounds obvious today, but probably only dates back to 1966—see [Barany 2015].

[119] See [Barany 2018], p. 271.

[120] Incidentally, the 16 Fields Medalists of the most recent period, 2006–2018, came from 12 different parts of the world (in the sense introduced in Section 10.4.1), and were still employed in 8 different parts of the world at the moment of their award. This is by far the most geographically diverse group of all the time periods.

[121] Cf. the corresponding loose discussion in [Bannister & Teschke 2018].

10.5.3 Plenary Speakers

Instead of the medals, we turn to the plenary lecturers at the ICMs during the past seventy years. The following Fig. 10.13 shows two possible classification breakups of their production. On the left, we simply count the plenary lectures themselves according to the subdomains they can be associated with.[122] The second way of counting the production of our plenary speakers is by looking at all the papers they published at about the same time as their plenary talk.[123] The breakdown of these publications is shown on the right in Fig. 10.13.

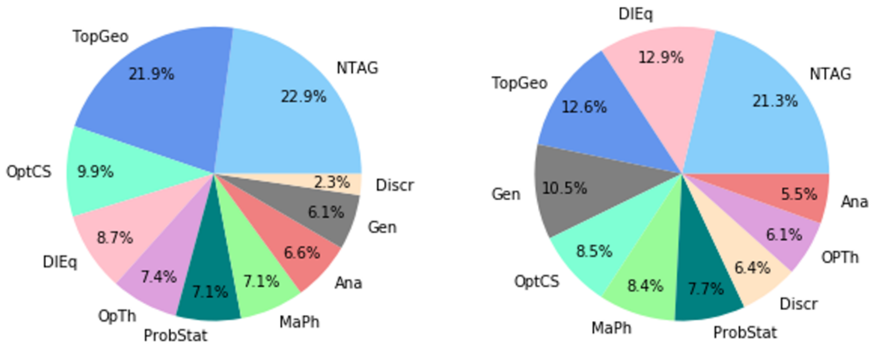

Fig. 10.13 Plenary Lectures, 1950–2020 (left); all publications of plenary speakers around their plenary talk, 1949–2020 (right).

The difference between Fig. 10.12 and 10.13 is blatantly obvious. Of the four domains that take the lead in Fig. 10.12, only Differential & Integral Equations reaches again a score above 10% in one of the charts of Fig. 10.13. Optimization (including Computer Science) still comes in third in the count of the Plenary Lectures (the left-hand chart). Mathematical Physics, and Probability & Statistics definitely lose their prominent positions. The new leader is Number Theory/Algebra/Algebraic Geometry/Group theory, which we call *NTAG*. This and Topology/Geometry are the

[122] Only for the lectures that were published in the ICM Proceedings do we have an MSC classification. This, by the way, is independent of whether the talk was actually delivered at the ICM or not. (In one exceptional case, the classification is that of an independent publication with the same title as the lecture.) In this way, no classification data are available for 20 invited lectures. The total number of talks available with their classifications is 315.

[123] Specifically, for a speaker who delivered a plenary lecture at the ICM in the year N, we look at the classifications of all the papers (co-)authored by that speaker that appeared in the four year interval $[N-1, N+2]$. This includes the plenary lecture itself, if it was published. We again acknowledge the generous access to the zbMATH Open data without which this analysis could not have been realized.

two newcomers from pure mathematics in the upper tier of the survey of publications by plenary speakers.

Both charts shown in Fig. 10.13 can be broken up according to our five time periods, instead of considering all the seventy years at once. When one does this for the plenary lectures themselves (i.e., the chart on the left), the dominance of *NTAG* and *TopGeo* shows in every single period, and *OptCS* comes in third in all periods but the first one (1950–1962), which is the only period where both *OpTh* (9.7%) and *Ana* (9.0%) compete with *DIEq* (9.0%) to break the 10% threshold, whereas *OptCS* does not even attain 5%.

However, going through our five periods with a view to the publications of our plenary speakers at about the time of their ICM lecture, like in the breakdown on the right of Fig. 10.13, yields pie charts that vary a great deal.

For example, in Period 3: 1983–1990, the biggest share goes to the category General Mathematics/History/Foundations, which we call *Gen*. This is largely due to one particularly prolific person among the plenary lecturers, Saharon Shelah. He published 156 papers classified in this category around the same time as the 1983 and 1986 ICMs, 154 of them concern set theory. This personal contribution represents 16% of all papers published by plenary speakers of the third time period at about the time of their lectures, and boosts the *Gen* category to 19.8% among those publications.[124]

In Period 4: 1994–2002, the three strongest specialities are Mathematical Physics, Differential & Integral Equations, and Optimization/Numerical Analysis/Computer Science; only then follow *NTAG* and *TopGeo*.

We have looked a bit more into the most prolific authors of our population, and into publication patterns according to the different categories, in particular the frequency of co-authored papers. The proportion of co-authored papers in our population increases gradually over time, from altogether less than 30% in Period 1 to more than 70% in Period 5. But the variation between the different specialities is considerable. The domains *Discr* and *OptCS* show the highest proportions of co-authored papers.

[124] Incidentally, considering the total publication record, Shelah is the second most prolific author of our whole population, topped only by Erdős. Both of them were awarded the Wolf Prize; Erdős in 1983, and Shelah in 2001, when he was the first mathematician born in Israel to win this award.

10.5.4 Filtering the Mathematical Production

We could end here. Instead, let us pry into the matter from a different point of view. We would like to capture the subject distribution of the plenary lectures in terms of a selection procedure which is not immediately linked with the IMU or the ICMs. The hope is to gain a new perspective on the choices made for the ICMs. To do this, we have turned to the internal work flow of zbMATH Open.[125]

No working mathematician can keep abreast of all mathematical publications; everyone has to prioritize her or his attention, according to her or his special interests, within the large field of mathematics, and through a personal ranking of the mathematical journals she or he will try to follow. In other words, we all apply our personal filters in monitoring the incessant production of the mathematical literature. What happens to the Cupola of the ICMs when we look at it through such a lens? To be sure, biases in favor of certain branches of mathematics have to be avoided in the analysis; the effect of being keenly interested by plenary lectures on topics near one's own research domain—however well presented other talks may be, to the large crowds gathering at the ICMs—is as natural as it is uninteresting for the kind of filtering we are looking for. Is it possible to trace the production of all the plenary speakers by carefully selecting journals without any prejudice with respect to subdomains of mathematics?

The first idea could be to look only at *Generalist Journals*, in the sense explained in [Mihaljević & Teschke 2014].[126] These journals try to publish good mathematics in an unbiased way with respect to mathematical subdomains. The problem with this approach is that the percentage of the papers of our plenary speakers published in generalist journals turns out to be too small to be a fair reflection of their productivity. Therefore we had to look for other filters adapted to our problem.

All mathematical journals whose articles are treated by zbMATH Open, with a view to being reviewed, are categorized by the zbMATH Open editorial board according to their expected scientific quality, and with a view to keeping a reasonable balance between specialized journals and those that try to cover many branches of mathematics. The most prestigious category, for which every editor was allowed to make a limited number of proposals, is internally called *Fast Track*; the papers in these journals receive the most speedy treatment. Once all the Fast Track slots are filled, the board decides on the next best journals, called *Category 1*. And so forth. When journals change their profile as time goes by, the zbMATH Open editors try to react swiftly and re-categorize them if necessary. Our access to the zbMATH Open data included this categorization of all the journals.

The zbMATH Open procedures just described go back to the first years of the twenty-first century. In spite of individual journals that may change categories, the hierarchy is generally quite stable. It essentially still reflects a configuration that

[125] Once more we thank Olaf Teschke for providing the necessary background information.

[126] Cf. [Grcar 2010].

was recognized by the editorial board in the early years of this century. The years before the turn of the century had clearly contributed to shaping this configuration. Indeed, we have checked that no major discontinuity occurred around 2000 for the breakdowns we have been studying. All this encouraged us to look at the period 1993–2020, and filter papers of the Plenary Speakers according to the internal zbMATH Open categories of journals they were published in.

For the time interval 1993–2020, the Fast Track journals published about 13.6% of all mathematical papers. If one adds to this the Category 1 journals, we attain 38.6% of the total mass of publications. Altogether 989,332 papers have been treated in FT & Cat. 1 journals between 1993 and 2020, of which 1,404 were (co-)authored by plenary speakers in chronological vicinity to their ICM talks, as explained above. The corresponding classification breakdowns are shown in Fig. 10.14.

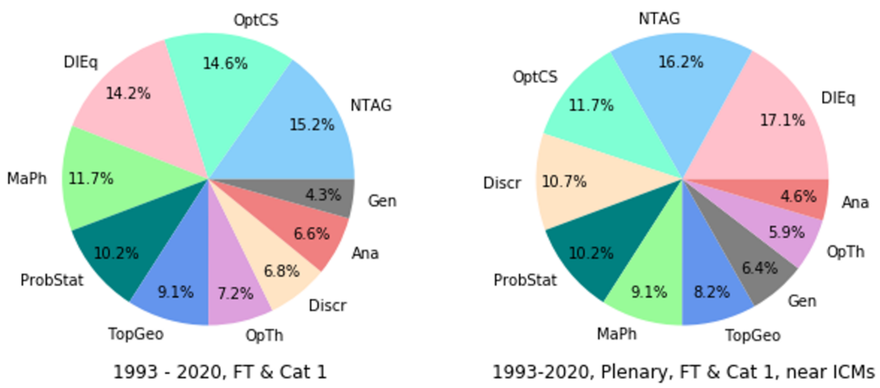

Fig. 10.14 Comparing all publications in Fast Track and Cat. 1 journals between 1993 and 2020 (left), to those (co-)authored by Plenary Speakers around their plenary talk (right).

In spite of a slight reshuffling of several shares, the overall resemblance of the two sets of papers is remarkable. This suggests that the class of journals chosen for this comparison is rather well adapted to the production of the plenary speakers of the last seven ICMs. In other words, the selection procedures for the Cupola of those ICMs appear to be by and large compatible with the internal hierarchization of mathematical journals practiced by zbMATH Open.

There are two special phenomena visible in Fig. 10.14 that should be mentioned. The first one is the unexpectedly strong share of Discrete Mathematics & Convex Geometry among the publications of the Plenary Speakers. This is due to the fact that Plenary Speakers in this domain, between 1993 and 2020, tended to be markedly more prolific than those of the other specialities. Indeed, for each mathematical domain we have computed the rate of publications of Plenary Speakers, in the four year interval about their ICM lecture as was explained above.[127] The domain *Discr* distances itself from all other specialities, with a median value of 259 papers per speaker, more than twice the median of all domains taken together.

The second peculiarity becomes apparent when one compares the charts in Fig. 10.14 and 10.13. Even though the latter apply to the total period since the 1950s, one immediately wonders why Topology/Geometry, which gets a conspicuous share of the cake, does so poorly in Fig. 10.14. As a matter of fact, the discrepancy is just as dramatic if one replaces the diagrams of Fig. 10.13 by the corresponding ones for the last two time periods. The explanation of this effect lies again in the publication pattern of the domain. In fact, two factors contribute: The 'papers per speaker' rate for *TopGeo* is only 11, the lowest rate of all domains. Furthermore, it turns out that the speakers in this domain, and in those years, tend to publish an unusually high share of their papers not in journals, but rather in conference proceedings and other multi-author volumes.

[127] More precisely, all speakers are fractionally counted with equal weight for each one of the domains that appear in the classification of their plenary lectures, and the same is done for every publication in the $[N-1, N+2]$ time interval.