2019 REPORT OF THE ICM STRUCTURE COMMITTEE

TERENCE TAO (CHAIR), CARLOS KENIG (*EX OFFICIO*), NALINI ANANTHARAMAN, ALEXEI BORODIN, ANNALISA BUFFA, HÉLÈNE ESNAULT, IRENE FONSECA, TERRY LYONS, STÉPHANE MALLAT, HIRAKU NAKAJIMA, ÉVA TARDOS, PETER TEICHNER, AKSHAY VENKATESH, ANNA WIENHARD

1. Introduction

The inaugural Structure Committee was constituted on January 1, 2019, and was tasked with deciding the structure of the Scientific Program of the International Congress of Mathematicians (ICM), 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.

In this regard we were guided by a report from a previous *ad hoc* committee, chaired by László Lovász, to look into these matters. (This was necessary due to the abbreviated schedule for this inaugural committee, which only began work three years before the ICM instead of five years before.)

Our committee was also initially chaired by Lovász. We began our deliberations on a private blog of the International Mathematical Union, focusing first on proposals to change the format of the ICM in a substantial way, in particular by exploring non-standard types of plenary or sectional talks. We also sent out a questionnaire to participants of the 2018 ICM, and also posted on the personal blog of one of the committee members (Tao), to invite feedback on this new committee.

On February 15, 2019, Lovász stepped down as chair of the Structure Committee to attend to domestic political matters, and Terence Tao took over the chairmanship position. (Lovász would later resign on June 24 due to these matters.) In early March, we presented our preliminary proposals to the Executive Committee and to the chairs of the Program Committee and Organizing Committee to obtain further feedback, and arranged for a face-to-face meeting to be held in Paris on July 6–7. On March 21, 2019, János Kollár stepped down from the committee due to health reasons (though he agreed to still participate in the online discussion in a limited fashion), and Hélène Esnault took his place on the committee.

In April, we initiated the main task of subdividing the various mathematical fields into sections. We began by contacting past Program Committee and sectional panel chairs for their input. This feedback was immensely valuable and we plan to continue this practice in future years. (Related to this, in the past the Program Committee had contacted sectional panels for their input on revising the section descriptions and the longer justifications for each section; we will coordinate with the Program Committee to obtain this input going forward.)

At our face-to-face meeting in July 6–7 in Paris, attended in person by all active committee members (except for one member who participated remotely), we arrived at a consensus for our various proposals to change the structure of the next Congress, as well as to suggest further initiatives relating to the Congress for other related committees to consider. The most major and important changes we propose in this regard involve setting aside a non-trivial fraction of both the plenary and sectional talks for "special" lectures that deviate from the standard format of having a talk on a recent significant research accomplishment by one of the key mathematicians responsible for that accomplishment. We also made significant changes to the division of the sections, most notably by replacing what was formerly Section 17 (Mathematics in Science in Technology) with two new sections, now numbered Section 17 (Statistics and Data Analysis) and Section 18 (Stochastic and Differential Modeling), with the new Section 17 also absorbing half of what was formerly Section 12 (Probability and Statistics), with the remaining half that section continuing as Section 12 (Probability). We will explain our rationale for these changes, as well as a number of more minor changes and recommendations, in subsequent sections of this report. These proposals evolved somewhat from earlier preliminary versions that had previously been presented to the Executive Committee or which were contained in the *ad hoc* report, but after extensive discussion, the final form of these proposals achieved unanimous support of the entire Structure Committee.

Shortly after our face-to-face meeting, we also revised the descriptions of each section, as well as the longer justification of each section. We plan to keep in contact with the Program Committee in order to update these descriptions and justifications, should this become necessary.

The committee wishes to thank the Hugot Foundation for their outstanding hospitality in hosting our Paris meeting.

2. Current state of the Congress

The International Congress of Mathematicians is widely regarded as the premier gathering of mathematicians. Meeting every four years under the auspices of the International Mathematical Union (IMU), the Congress plays a unique role in mathematics, both by recognizing exemplary recent research achievement in all of the various subfields of mathematics, and by giving the broader community of mathematicians the opportunity to learn about the latest mathematical research developments, and to interact with leaders in the field. This latter aspect of the Congress is particularly valuable for doctoral students, postdoctoral and junior researchers, and mathematicians from developing countries, who might otherwise have only limited ways to interact with such leaders.

Many of the lectures at the Congress thus 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. The approximately 180 sectional lectures, divided across 19 or 20 sections representing different general areas of mathematics, are held in highly parallel sessions, and are more attended by specialists, but continue to be viewed as a high honor, both for the speaker and for the department that the speaker is affiliated with. Though there are exceptions, the sectional lectures have typically recognized recent significant research developments in one of the subfields covered by the sections (or, increasingly, in subfields covered by two or more sections, resulting in a joint talk shared between sections), and are given by a mathematician that played a leading role in these developments. The 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 (such as the quality of the Congress proceedings, or the ability to view talks online), 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; while many talks were excellent and pitched appropriately to the target audience, some of the lectures presumed too much specialist knowledge, or were perceived as not making enough of an effort to engage with the typical members of the audience, who may be in a different field than the speaker. 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. For sectional lectures, this led to the embarrassing spectacle of some of these lectures being extremely sparsely attended.

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. In principle, the ICM offers a uniquely promising opportunity for pure and applied mathematicians to come together and learn about the latest exciting developments at the interface between these two sides of mathematics; however, the feedback we collected indicated that the actual level of interaction between these two communities was less than what might be hoped. The situation here can be contrasted with that of another major conference in mathematics, the International Congress on Industrial and Applied Mathematics (ICIAM). The latter conference involves a relatively small number of participants identifying as "pure" mathematicians, and is focused more on the interface between applied and industrial mathematics, rather than the interface between pure and applied. Also, there is significantly less emphasis at ICIAM on the prestige attached to a speaker invitation. The two congresses thus complement each other, but offer only modest opportunities for synergy.

The issues discussed above had also been identified prior to the work of our own committee, and in particular were discussed by the *ad hoc* committee preceding our own; our committee also resolved to make the resolution of these issues our top priorities. Some of the preliminary recommendations of the *ad hoc* committee served as a starting point for the evolution of our own committee proposals, and will be discussed below.

As mentioned in the introduction, the Structure Committee solicited feedback from the previous Program Committee Chair (János Kollár, who also served for some time in the current committee), as well as all sectional panel chairs. While most sections reported general satisfaction with the scope, coherence, and description of their section (or requested only fairly minor changes), two sections in particular reported serious difficulties. The most significant issues were with Section 17 (Mathematics in Science and Technology), which aimed to cover applications of mathematics to an extremely broad range of areas, such as the physical sciences, life sciences, social and economic sciences, and technology. Given this breadth, it was not possible to assemble a committee that could cover all of these areas adequately, and many of the talks selected were quite disparate from each other, both in application domain and in mathematical methodology. In some previous Congresses, an attempt was made to restrict the focus of this section to a narrower set of topics that would rotate with the Congress, but this was quite poorly received by the various communities involved, and the *ad hoc* committee strongly recommended against reviving this practice, a verdict which our own committee concurred with. The *ad hoc* committee also recommended that instead of sorting applied mathematical topics by application domain, they should be grouped according to common mathematical methodologies, in order to capitalize on the Congress's position at the interface between pure and applied mathematics. Our final proposals regarding this section, to be detailed below, were influenced by this recommendation.

While less severe, problems were also reported with Section 9 (Probability and Statistics). On paper, this would appear to be an example of a section that combines both pure and applied mathematical topics in an integrated fashion (which was another recommendation of the *ad hoc* committee). However, in practice, the committee effectively split into two disjoint and non-interacting subcommittees, with the probability speakers being recommended by one subcommittee, and the statistics speakers being recommended by the other. Despite the shared history of the two subjects in the past, the modern focal points of Probability and Statistics were now sufficiently distinct that both the sectional panel chair and the program committee chair felt that there was no longer significant synergy to be had by keeping them in the same section, and recommended separating them into different sections.

The feedback we collected during our committee work also raised some other concerns of potential interest to either the Organizing Committee or the Program Committee, some of which which we have recorded in the appendices to this report.

3. Main structural proposals

Our committee unanimously proposes the following major changes to the sectional and plenary lecture structure.

3.1. **Sectional lectures.** We want the Congress to address the evolution of the frontiers of mathematics, and its interactions with applications, in a more organic and creative fashion. Specifically, we wish to encourage sectional panels to experiment with more lectures outside of the standard format, by which we mean a lecture in which a recent significant research accomplishment in a field is presented by one of the key mathematicians responsible for that accomplishment. To achieve this goal, we have reduced slightly the base number of recommended slots to several sections; these base slots will continue to be allocated to "standard" sectional lectures by the procedures followed by past Program Committees. However, the Program Committee will now also retain twenty discretionary sectional slots to award to sections for "special sectional lectures" that promise to offer additional value beyond that given by a standard sectional lecture. Examples of such special lectures could include:

- A talk that creates new connections between different areas of mathematics and its applications, and in particular has the potential to bring communities from both fields closer to each other.
- A talk that does not fit neatly within existing section structures, for instance due to a highly interdisciplinary nature, or because it represents an emerging mathematical area not adequately covered by existing section descriptions.
- A timely survey of a subfield of a section, given by an expert who may not necessarily be directly involved in the most recent developments.

- A talk that involves an unusual but promising methodology or format that would not often be seen in standard sectional lectures.

Of course, in all of the above examples it is expected that the scientific quality of the talks still be at the highest levels. However, we envisage that some special sectional talks may be more experimental in nature, and could be permitted to take more risks than would be acceptable for a standard sectional lecture.

Sectional panel chairs will make "bids" for these additional slots, putting forward suggestions for individual speakers, together with a rationale for these speakers, to the Program Committee, who will have the final say on how the discretionary slots are allocated. This process will be separate from the process for nominating speakers for standard sectional lectures, and will also be separate from the existing ability of sectional chairs to split slots with other sections for joint speakers, although two or more sectional chairs can jointly make a bid for a discretionary slot for a proposed speaker. Special sectional lectures would be designated as such on the official schedule of the Congress, to distinguish them from the standard sectional lectures. The Structure Committee will take the selection of these discretionary slots into account in future years to determine how the sections evolve in response to emerging developments. The Structure Committee will also work with the Program Committee to implement this proposal as smoothly as possible.

3.2. **Plenary lectures.** We wish to give the Program Committee increased flexibility in determining the plenary lectures, in order to adapt the exposition to the very large and diverse audiences these lectures have. We therefore propose to keep the number of plenary lectures at approximately 20, but designate two or three of these lectures as "special plenary lectures" that will have a non-standard format, such as expository lectures on recent advances by other mathematicians, "bridge building" lectures connecting two fields of mathematics (such as a pure and an applied field), lectures given jointly by two speakers, or other experimental formats. Circumstances in which such talks might be preferred over a standard plenary talk include

- a topic in which two or more research groups made recent contributions;
- a topic in which the most natural speaker involved has already been a recent speaker at the Congress; or
- a "hot topic" requiring a "big picture" talk from an expert with the appropriate perspective.

Sectional panels should be informed of the various possible formats for plenary speakers, and can nominate plenary speakers for any of these formats. Special plenary lectures will be listed as such on the schedule of the Congress, to distinguish them from standard plenary lectures.

For all of these types of plenary lectures, we expect that the level of exposition be exemplary, even if the current guidance only requires that these speakers be "good" lecturers. Accordingly, in the invitation letter to plenary speakers, the responsibilities of effectively communicating their mathematics to a large fraction of Congress participants should be stressed, and that a helper will be assigned to work with the speaker on achieving this goal (this scheme had been trialed in the 2014 ICM but should now be institutionalized for all future Congresses). Invitees who are unwilling to give a plenary talk at the expected level of exposition can be offered a special sectional lecture slot instead, taken from the Program Committee's discretionary supply of such slots. We recommend that expository helpers be also assigned to the *laudatio* speakers, although we do recognize the possible complications this may cause with the need to keep the laureate's identity confidential. (One can consider drawing on members of the prize committee to serve as such helpers.)

The Structure Committee also seriously discussed the possibility of increasing the total number of plenary lectures, and explored several potential changes to the structure that would enable this to be possible, such as reducing the length of the sectional or plenary lectures, moving some sectional lecturers to satellite conferences, increasing the number of sectional lectures held in parallel, or allowing some plenary lectures to also be held in parallel. However, all of these options were rejected as having too many undesirable side-effects, and hence we recommend keeping the number of plenary lectures (including the new "special plenary" lectures) close to the current target value of 20, and keeping the length of lectures unchanged at one hour for both types of plenary lectures, and 45 minutes for both types of sectional lectures. However, if all the discretionary sectional slots of the Program Committee are allocated, the total number of sectional speakers may increase slightly from its current target of 180, perhaps to as high as 195. We believe that it should still be possible to accommodate this number of sectional speakers in the calendar of the Congress without significant additional changes. However, the Program Committee is not obliged to allocate all of the discretionary sectional slots, in the event that there is an insufficient number of satisfactory bids for such slots.

4. Recommended section descriptions and base allocations

The Structure Committee unanimously recommends the following revision of the section structure, and the number of base lecture slots allocated to each section (excluding the 20 discretionary slots retained by the Program Committee). After each description and justification, we give a brief commentary on the changes made in each section in comparison to preceding Congress.

Section 1. Logic (3–5 base lecture slots).

Description: *Model theory. Proof theory. Recursion theory (Computability theory). Set theory. Applications.*
Connections with Sections 2, 3, 4, 8, 13, 14.

Justification: Mathematical Logic grew out of the quest for sound foundations and rigor in the mathematical enterprise, but finds significant application to non-foundational issues. The main streams took shape in the period beginning with the creation of Set theory by Cantor in the late nineteenth century, through the foundational program of Hilbert, and culminating in the work of Gentzen, Gödel, Tarski, and Turing in the early twentieth century. Major current themes include: independence questions, large cardinals, strength of logical systems, reducibility in computability hierarchies, definability, stability and minimality notions. The subject is a rich symbiosis of foundational questions, internal development, and applications (including to algebra, algebraic and complex geometry, combinatorics, computer science, number theory, and various parts of analysis). Recently, homotopy type theory has also emerged as a new type of proof theory that has connections to topology.

Commentary: Few problems were reported with this section. The main changes from 2018 are to add connections to Section 4 (Algebraic and Complex Geometry) and Section 8 (Topology), with the latter arising primarily from the emergence of homotopy type theory, which is now also mentioned in the justification. The traditional field of Recursion theory is now also referred to by the more modern name of Computability theory. The previous sectional panel chair also noted that it could be beneficial to have a member of the panel who was aware of developments in theoretical computer science that would have connections to logic.

Section 2. Algebra (3–6 base lecture slots).

Description: *Groups (finite, infinite, algebraic) and their representations. Rings (both commutative and non-commutative), fields and modules. General algebraic structures, algebraic K-theory, category theory. Computational aspects of algebra and applications.*
Connections with Sections 1, 3, 4, 5, 6, 7, 13, 14.

Justification: Algebra is a fundamental subject in mathematics, and has especially close connections with algebraic geometry, topology, combinatorics and number theory. Many of its traditional subjects are very active (e.g. finite groups and their representations, algebraic K-theory, field arithmetic, etc.) and in other topics interactions with other areas have been very important (e.g. algebraic groups, Lie theory, algebraic geometry, combinatorial group theory, category theory, etc). The panel should pay especially close attention to a proper balance between these two aspects of the field.

Commentary: Few problems were reported with this section, with the description being largely unchanged from the previous update in 2014. The committee received a proposal to move commutative algebra to Section 4 (Algebraic and Complex Geometry), and also to move aspects of representation theory from Section 7 (Lie Theory and Generalizations) into this section, but there did not appear to be a strong desire within the algebra community for these changes, and the committee felt that the benefits of such moves were too slight to warrant a reorganization at this time. However, we modified the justification slightly to stress the interconnections of algebra with Lie theory and with algebraic geometry.

Section 3. Number Theory (8–11 base lecture slots).

Description: *Algebraic number theory. Galois groups of local and global fields and their representations. Arithmetic of algebraic varieties and Diophantine equations. Geometry of numbers, Diophantine approximation, and transcendental numbers. P-adic analysis. Modular and automorphic forms, modular curves, and Shimura varieties. Langlands program. Zeta and L-functions. Analytic, additive and probabilistic number theory. Computational number theory and applications. Relations with logic and with physics.*
Connections with Sections 1, 2, 4, 7, 9, 11, 12, 13, 14.

Justification: Number theory is one of the oldest branches in mathematics, stimulating the development of many other branches including complex and p-adic analysis, algebra and algebraic geometry..., and it is still thriving today. Research in algebraic number theory has focused on fundamental properties of Galois representations and L-functions, with deep connections, on the one hand, to algebraic geometry, as envisioned by Grothendieck's conjectures on motives, and on the other hand, to representations of Lie groups and automorphic representations, as stipulated by the Langlands conjectures. Analytic number theory, with traditional focus on distribution of primes, has undergone a great revival in recent years, achieving solutions of longstanding problems, with new connections with combinatorics and probability. Because of the often concrete nature of number theoretic problems, computational number theory is also very active and entertains a strong connection with theoretical computer science.

Commentary: Few problems were reported with this section. Connections with logic were mentioned in the introduction, and analytic, additive, and probabilistic number theory were grouped together. Connections with Section 9 were added due to the addition of homogeneous dynamics to that section. The justification has not been significantly revised this year, but we may revisit it in forthcoming years.

Section 4. Algebraic and Complex Geometry (8–11 base lecture slots).

Description: *Algebraic varieties, their cycles, cohomologies, and motives. Schemes and stacks. Geometric aspects of commutative algebra. Arithmetic geometry. Rational points. Low-dimensional and special varieties. Singularities. Birational geometry and minimal models. Moduli spaces and enumerative geometry. Transcendental methods and topology of algebraic varieties. Complex differential geometry, Kähler manifolds and Hodge theory. Relations with mathematical physics and representation theory. Computational methods. Real algebraic and analytic sets. p-adic geometry. D-modules and (iso)crystals. Tropical geometry. Derived*

categories and non-commutative geometry.
Connections with Sections 1, 2, 3, 5, 6, 7, 8, 11, 13, 14.

Justification: Algebraic, arithmetic and analytic geometry lie at the crossroads of many developments in mathematics. It has especially close connections with Algebra, Number Theory, Topology, Differential Geometry and Mathematical Physics. Many of the modern developments in this area are deeply influenced by these related fields, and influence them in turn. The tools required to work in this area are diverse, ranging from complex analysis to finite field and p-adic techniques. Some fundamental ideas in the subject are profound, such as motives, moduli, or the way to go from the complex numbers to finite fields and back. In recent years, there have been a number of spectacular advances in birational geometry, moduli theory, D-modules and isocrystal theory, diophantine geometry, in the geometric study of derived categories, enumerative geometry and in motivic questions.

Commentary: Few problems were reported with this section. The description and justification were expanded slightly to include a reference to p-adic geometry and D-modules, as well as connections with logic.

Section 5. Geometry (8–11 base lecture slots).

Description: *Local and global differential geometry. Geometric partial differential equations and geometric flows. Geometric structures on manifolds. Riemannian and metric geometry. Kähler geometry. Geometric aspects of group theory. Symplectic and contact manifolds. Convex geometry. Discrete geometry.*
Connections with Sections 2, 4, 6, 7, 8, 9, 10, 11, 12, 16, 17.

Justification: Geometry plays a central role in the development of mathematics, especially in the late 20th century and the early 21st century. Applications of nonlinear PDEs to geometry were started in the last century, and still continue to expand (e.g., pseudo-holomorphic curves in symplectic and contact geometry yield new invariants). Riemannian and metric geometry are traditionally a central theme in geometry, and also have applications to other areas (e.g., group theory, 3-manifolds topology, rigidity, probability, etc). Geometric structures on manifolds that are not necessarily metric (e.g projective, affine, and pseudo-Riemannian structures) have seen important recent developments, and geometric approaches became prominent in the study of both discrete groups as well as locally compact groups.

Commentary: Apart from a concern that there were relatively few speakers in this section in 2018 (12 speakers using 9.5 slots, as opposed to 16 speakers using 13.5 slots in 2014 and 13 speakers using 12.5 slots in 2010), few problems were reported with this section. As with many other sections, the maximum number of allocated base slots has been reduced slightly compared to 2018, but for Geometry we did not lower the minimum number. The description has been left mostly unchanged from 2018, but the justification has been extended to explicitly discuss geometric group theory.

Section 6. Topology (7–10 base lecture slots).

Description: *Algebraic, differential and geometric topology. Surgery and diffeomorphism groups of manifolds. Homotopy theory, including motivic homotopy and K-theory. Operads and higher categories. Floer and gauge theories. Low-dimensional manifolds including knot theory. Moduli spaces. Symplectic and contact manifolds. Aspects of quantum field theory.*
Connections with Sections 2, 3, 4, 5, 7, 8, 9, 11.

Justification: Depending on the methods used, the subject is divided into Algebraic Topology, Differential Topology, and Geometric Topology. In its various forms it is essential to many core areas of mathematics including Geometry, Arithmetic, Analysis, Algebraic Geometry, Dynamical Systems and Mathematical Physics, and its methods are widely used in an increasing number of applied areas of mathematics. Recent years have seen major advances on some classical problems in 3- and 4-manifold theory, equivariant stable homotopy theory (Kervaire invariant), and the study of moduli spaces. At the same time newer subject areas such as geometric group theory, topological quantum field theory, and derived algebraic geometry have seen important developments which have shaped the topological landscape. Major topics include manifold theory, homotopy theory (including motivic homotopy and K-theory), operads and higher categories, Floer and gauge theories, low-dimensional manifolds including knot theory, moduli spaces, symplectic and contact manifolds, and aspects of quantum field theory.

Commentary: Few problems were reported with this section, although the panel chair reported some operational problems with ensuring geographic diversity, and with lack of guidance on whether "lifetime achievement" was a suitable justification for a section nominee (we believe this latter problem may be resolved with our proposal to introduce special sectional lectures). The description and justification have been slightly reworded from the 2018 versions.

Section 7. Lie Theory and Generalizations (6–9 base lecture slots).

Description: *Structure, geometry, and representations of Lie groups, algebraic groups, and their various generalizations. Related geometric and algebraic objects, e.g., symmetric spaces, buildings, and other Lie theoretic varieties, vertex operator algebras, quantum groups. Lattices and other discrete subgroups of Lie groups, and their actions on geometric objects. Non-commutative harmonic analysis. Geometric methods in representation theory.*
Connections with sections 2, 3, 4, 5, 6, 8, 9, 11, 12, 13.

Justification: Lie groups and Lie algebras are one of the major axes of mathematics, capturing the concept of a continuous symmetry. They are extended and generalized in various directions, such as infinite dimensional Lie algebras, Hecke algebras, quantum groups, or vertex operator algebras. Their structures and representations are often related to each other in deep ways, via D-modules or categorical equivalences. These find a multitude of applications in algebraic geometry, mathematical physics, harmonic analysis, number theory, and other areas. Structural results for Lie groups are also extended to locally compact groups. Another important direction is the study of discrete subgroups of Lie groups and their actions on geometric objects. Besides its intrinsic interest, this area has found connections and applications to mathematical physics, geometry, number theory, ergodic theory, dynamics, and even computer science.

Commentary: This section is unusually eclectic in nature, for instance being the only section explicitly named after an individual mathematician. We received a proposal to dissolve this section and move various components of it to Section 2 (Algebra), Section 3 (Number Theory), Section 4 (Algebraic and Complex Geometry), and Section 9 (Dynamics). However, the previous sectional panel chair felt that the scope of the section was fine as is, and so we have only made minor changes for the next Congress, most notably moving homogeneous dynamics into Section 9 (Dynamics), and adding mentions of Lie theoretic varieties and actions on geometric objects, as well as representation theory and extensions to locally compact groups (such as totally disconnected groups). We may however revisit the possibility of more drastic changes to this section in subsequent years.

Section 8. Analysis (9–12 base lecture slots).

Description: *Classical analysis. Real and Complex analysis in one and several variables, potential theory, quasiconformal mappings. Harmonic, Fourier, and time-frequency analysis. Linear and non-linear functional analysis, operator algebras, Banach algebras, Banach spaces. Non-commutative geometry, free probability, analysis of random matrices. High-dimensional and asymptotic geometric analysis. Metric geometry and applications. Geometric measure theory.*
Connections with sections 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17.

Justification: Analysis in the broad sense is one of the main areas of mathematics. This section includes complex analysis, harmonic analysis (both real-variable and abstract), functional analysis, operator algebras, geometric measure theory, and high-dimensional geometry. The subject combines quantitative estimates with qualitative results, and can be applied in both continuous and discrete settings. The classification and analysis of operator algebras such as von Neumann algebras and C^* algebras has deep connections with such diverse areas of mathematics as geometric group theory, descriptive set theory, and ergodic theory. The analysis of integral operators (singular, oscillatory, potential, Fourier, etc.), and related objects such as pseudodifferential operators, has many applications to partial differential equations, index theory, geometry, mathematical physics, and number theory. There have been many further fruitful interactions between analysis and other areas, such as dynamical systems, probability, combinatorics, signal processing, and theoretical computer science.

Commentary: The role of operator algebras and functional analysis in this section has oscillated significantly in past Congresses. In 2010, these topics were separated from Section 8 and placed in a small experimental section. In 2014, these topics were folded back into Section 8 (which was renamed "Analysis and its applications"), but only two of the 15 talks in that section (using $12\frac{2}{3}$ slots) had any connection to operator algebras. In 2018, the section was renamed again to "Analysis and operator algebras" and significantly enlarged, with significant representation of the latter on the panel committee, and of the 20 talks in the section (using 16.5 slots), five could be viewed as in operator algebras or functional analysis; the panel chair reported that panel effectively decoupled into an operator algebra panel and an analysis panel who largely selected their own speakers. On the other hand, the 2018 description and justification of the section was unchanged from 2014.

For 2022, we have aimed for an outcome intermediate between the 2014 and 2018 Congresses, by renaming the section back to "Analysis" and reducing the size back to 2014 levels (though it still remains the largest section in the Congress), but increasing the visibility of operator algebras in the description and justification, for instance by explicitly mentioning free probability in the description, and discussing the connections of operator algebras with other fields of mathematics in the justification. The topic of random matrices is shared between this section and Section 12, but we believe it is natural for this topic to lie in both sections. The justification has been expanded in other ways to emphasize breadth and diversity of application. We will continue to monitor the effectiveness of this section in future years in order to evolve it to a more stable state.

Section 9. Dynamics (8–11 base lecture slots).

Description: *Topological and symbolic dynamics. Smooth dynamical systems, including those derived from ordinary differential equations. Hamiltonian systems and dynamical systems of geometric origin. One-dimensional, holomorphic and arithmetic dynamics. Dynamics on moduli spaces. Ergodic theory, including applications to combinatorics and combinatorial number theory. Actions of discrete groups and rigidity theory. Homogenous dynamics, including applications to number theory. Infinite dimensional dynamical systems and partial differential equations.*
Connections with Sections 5, 7, 8, 10, 11, 12, 13, 15, 16.

Justification: Strong tools from conformal geometry and from non-linear functional analysis were responsible for an impressive development of one-dimensional dynamics, both real and complex. Renormalization theory played a crucial role in understanding the small scale structure of these dynamical systems. More recently, renormalization was used also in two dimension dynamics in the study of Henon-like maps. Dynamical ideas related to renormalization were also fundamental in the solution of problems related to the spectrum of Schrödinger operators. Important developments have also occurred in chaotic dynamics, non-uniform hyperbolic systems, and partial hyperbolic dynamical systems. Many new properties of dynamical systems that are robust and generic in the C^1 topology were obtained in recent years. Several results were obtained on rigidity of actions of higher rank groups, and dynamical ideas on homogeneous spaces were successfully used to attack problems in number theory like the Littlewood conjecture. In the area of conservative dynamics, important results were obtained using analytic tools from KAM theory, as well as topological-analytic invariants from symplectic geometry.

Commentary: Following the suggestions of the previous section panel chair, we have renamed "Dynamics and Ordinary Differential Equations" to just "Dynamics", and downplayed the role of ODE in the description, to better reflect the current foci of activity in this subject (while still recognising the historical role that ODE has played in the development of dynamics). We have also transferred "homogeneous dynamics" from Section 7 to this section, and simplified the description somewhat by removing some overly specific topics. The justification has not been significantly revised this year, but we may revisit it in forthcoming years.

Section 10. Partial Differential Equations (8–11 base lecture slots).

Description: *Solvability, regularity, stability and other qualitative and quantitative properties of linear and non-linear equations and systems. Asymptotics. Spectral theory, scattering, inverse problems, deterministic and stochastic control theory, stochastic differential equations. Nonlocal equations, free boundary problems, calculus of variations, kinetic equations. Optimal transportation. Homogenization and multi-scale problems. Approximate solutions and perturbation problems. Relations to many applications.*
Connections with Sections 5, 8, 9, 11, 12, 15, 16, 17, 18.

Justification: Partial differential equations (PDEs) are used to model an extremely rich variety of scientific, probabilistic and geometric phenomena that are governed by wave propagation, reaction, diffusion, dispersion, equilibrium, conservation and more. Accordingly, PDEs are ubiquitous in science and engineering, including physical sciences, biology, economics and more recently, in social sciences. The pivotal role of PDEs within mathematics is realized through fruitful interaction with other areas, including analysis, geometry, mathematical physics, probability, control, numerical analysis, scientific computation and modeling. Important new tools were developed in recent years to enable better understanding of non-linear PDEs. There are still many challenging open problems that drive current research, including theories for global behavior of compressible and incompressible Euler and Navier–Stokes equations, the Yang–Mills equations and the Einstein equations, multi-scale analysis of singular perturbation problems, variational problems, and control and inverse problems with or without stochastic data.

Commentary: This is a large and diverse section, and some difficulties were reported in convening a panel that could adequately and fairly cover all developments in this subject. Our committee did not have an immediate proposal to mitigate this issue, but will continue monitoring the situation in coming years. The description has been updated to include quantitative properties, deterministic and stochastic control theory, stochastic equations, non-local equations, free boundary problems, kinetic equations and "approximate solutions and perturbative problems", with the scope of applications broadened. Section connections have been updated to reflect the splitting of the former Section 17 into the two new Sections 17, 18. The justification has been similarly broadened to include applications in biology, economics, and social sciences in addition to the more traditional physical sciences, as well as connections to scientific computation and modeling. The committee also added a mention of the Euler equations next to the Navier–Stokes equations, and made minor grammatical changes.

Section 11. Mathematical Physics (8–11 base lecture slots).

Description: *Dynamical systems, including integrable systems. Equilibrium and non-equilibrium statistical mechanics, including interacting particle systems. Partial differential equations including fluid dynamics, wave equation, Boltzmann equation and material science. General relativity. Stochastic models and probabilistic methods including random matrices and stochastic (partial) differential equations. Algebraic methods, including operator algebras, representation theory and algebraic aspects of Quantum Field Theory. Quantum mechanics and spectral theory, including quantum chaos. Quantum information and computation. Quantum many-body theory and condensed matter physics. Quantum field theory including gauge theories and conformal field theory. Geometry and topology in physics including string theory and quantum gravity.*
Connections with Sections 2, 4, 5, 6, 7, 8, 9, 10, 12.

Justification: Mathematical physics is situated at the interface between mathematics and physics. Ideas and questions from physics continue to have an enormous impact in many mathematical fields, like geometry, operator algebras, topology, probability theory, and PDEs, to name only a few. Mathematical physics is extremely broad, both by the mathematics it uses and contributes to and by the physical systems that it deals with.

Commentary: The only issue reported with this section was the wide breadth of topics and the large number of promising speakers within this area, although so far this issue seems to be manageable by making many speakers joint with other sections. For the next Congress, we have not changed the description or justification from the 2018 revision, and kept the speaker allocations unchanged (other than transferring one slot to the discretionary pool, as is done for many other sections).

Section 12. Probability (7–10 base lecture slots).

Description: *Stochastic analysis, Stochastic PDEs, Markov processes. Interacting particle systems, Random media. Random matrices and random graphs. Conformally invariant models, random growth models, exactly solvable models. Branching processes. Rough paths, regularity structures. Stochastic networks, Stochastic geometry. Applications in Statistics, Data Science, Computer Science,*

Physics, and Life Sciences.
Connections with sections 2, 3, 5, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 18.

Justification: The impact and influence of probability theory on the rest of mathematics, as well as on important aspects of our society, have been steadily growing over the last decades.

The connections with mathematical and statistical physics have always been very close, and fruitful for both sides. Within mathematics, the relations with PDEs and functional analysis have always been important. More recently, close interactions have grown with geometry (through geometric analysis and geometric group theory), with conformal field theory and complex analysis (through conformally invariant models), with representation theory and combinatorics (through integrable probability), and number theory (through random matrix theory).

The applications have also been expanding very rapidly, which directly lead to the creation of two new ICM sections (on Statistics and Data Science, and on Differential and Stochastic Modeling).

Commentary: This section previously encompassed both Probability and Statistics, but the previous section panel felt that there was no longer sufficient synergy between these two topics, with the panel effectively splitting into two non-interacting panels, one selecting probability speakers and one selecting statistics speakers. Accordingly, we have moved statistics into a new section (Section 17), joining it with data analysis, and kept probability in this section (though we envision that there will still be several talks in this section with connections to more applied topics). Currently active topics such as rough paths, regularity structures, and integrable probability have been added to the description and justification.

Section 13. Combinatorics (7–10 base lecture slots).

Description: *Combinatorial structures. Enumeration: exact and asymptotic. Graph theory. Probabilistic and extremal combinatorics. Designs and finite geometries. Algebraic combinatorics. Topological and analytical techniques in combinatorics. Combinatorial geometry. Combinatorial number theory. Additive combinatorics. Polyhedral combinatorics and combinatorial optimization.*
Connections with Sections 1, 2, 3, 4, 6, 7, 8, 9, 12, 14.

Justification: Discrete structures (such as graphs, set systems, matroids, or other diagrams and configurations) that exhibit a high degree of combinatorial complexity occur throughout mathematics, either as objects of interest in their own right, or as models for objects of importance in algebra, geometry, analysis, or theoretical computer science. The subject of combinatorics addresses many questions concerning these structures, ranging from enumerative questions such as counting how many objects of a certain size exist, to extremal questions such as the maximal and minimal values of various statistics associated to these objects, to structural questions concerning the nature of general objects in a given class of combinatorial structures, to more algebraic questions such as how such objects can be interpreted in such areas of mathematics as representation theory, commutative algebra, or algebraic geometry. Modern combinatorics uses techniques from across mathematics (probability, analysis, topology, algebra, etc.) and conversely is becoming an increasingly important component of new advances in many different disciplines (computer science, number theory, representation theory, logic, etc.).

Commentary: No problems were reported with this section. The description was updated to explicitly mention algebraic combinatorics, and the justification (last revised in 2014) was rewritten to emphasise the breadth and interconnections of the subject. A proposal to merge a significant portion of this section with Section 14 was briefly considered, but there did not seem to be strong need or support for such a change, and the proposal was soon dropped.

Section 14. Mathematics of Computer Science (5–7 base lecture slots).

Description: *Computational complexity theory, Design and analysis of algorithms. Automata and Formal languages. Cryptography. Randomness and pseudorandomness. Computational learning. Optimization. Algorithmic game theory. Distributed systems and networks. Coding and Information theory. Semantics and verification of programs. Symbolic and numeric computation. Quantum computing and information. Algorithmic and computational aspects in mathematics. Computational models and problems in the natural and social sciences.*
Connections with Sections 1-18, all constantly expanding.

Justification: The theory of computation is responsible for laying the mathematical foundations of all computing systems. It has developed, and continues to develop, theories supporting the exponential expansion of computer science and technology, with the necessary modeling, algorithms for them, and tools for analyzing the resources they expand. Such theories include, among many, the areas listed in the description. This work has created a web of interactions with many mathematical areas. The fundamental meta-problem of making the body of mathematics algorithmic (e.g. replacing existence theorems by efficient procedures to find these objects) has led to numerous more collaborations with practically every area of mathematics, greatly enriching many fields, unraveling finer structures, solving important problems and suggesting new challenges. A similar meta-problem of making the (natural and social) science algorithmic, namely study natural (often physical) processes as information processes using the computational complexity methodology, is creating mutually beneficial collaborations with most sciences. This viewpoint has already led to many collaborations, formal models, new insights (e.g., taking into account intractability results into modeling), results and problems, and will likely lead to much more in the future.

Commentary: Few problems were reported with this section. The previous section panel chair proposed a more modern revision of the description and justification of this subject that our committee has endorsed with only minor grammatical changes.

Section 15. Numerical Analysis and Scientific Computing (5–7 base lecture slots).

Description: *Design of numerical algorithms and analysis of their accuracy, stability, convergence and complexity for a wide class of (complex) problems with interests in applications. Numerical methods for high dimensional problems. Multiscale problems and probabilistic numerical methods. Approximation theory and computational aspects of harmonic analysis. Numerical reduction and uncertainty quantification. Numerical solution of algebraic, functional, stochastic, differential, and integro-differential equations.*
Connections with Sections 8, 9, 10, 12, 14, 16, 17, 18.

Justification: The use of mathematical models in science has a long tradition. Each model needs a numerical counterpart to be simulated with a computer and, often, the construction of such numerical models is a challenge, that has both mathematical and practical aspects. E.g., numerical instabilities may drastically reduce the quality of the solution and need to be understood and resolved, or the simulation of a full scale numerical model may be unfeasible, thus reduction techniques are needed. As a matter of fact, the design of effective numerical methods for complex problems requires the use of sophisticated mathematical tools, together with a deep understanding of the problem at hand and of the many practical aspects involved in the simulation.

This section should showcase the most important work in this field. Importance should come from the impact and insight the approach generates inside and also outside mathematics.

Commentary: Basically no problems were reported with this section. The description was expanded (in particular adding a connection to the new Section 18), and the justification was completely rewritten. This section will naturally also regroup some of the contributions of the previous Section 17 and, to this respect, is expected to include more application oriented contributions. Methods using tools from data science in the numerical modelling may play an increasing role.

Section 16. Control Theory and Optimization (5–7 base lecture slots).

Description: *Minimization problems. Controllability, observability, stability. Robotics. Stochastic systems and control. Optimal control. Optimal design, shape design. Linear, non-linear, integer, and stochastic programming. Inverse problems. Applications.*
Connections with Sections 9, 10, 12, 13, 14, 15, 17, 18.

Justification: Control and optimization have strong mathematical foundations and also play an important role in many engineering disciplines. Optimization has always provided motivation for many branches of mathematics, starting with calculus. Control theory provides the link between the most theoretical aspects of the subject (geometrical theory of dynamical systems) and more numerical, practical aspects (numerical optimization). In the modern setting, a range of disciplines use and develop these areas. Examples of applications include embarked automated systems, shape optimization for airfoils, solution of inverse problems for oil production. Traditional industries are increasingly demanding in terms of certification, virtual experimentation, thus optimization is still a very lively topic. In addition, new fields of application have appeared: life sciences (medical sciences, mechanics, computer aided surgery), smart materials, laser control of molecular evolutions (molecular electronics), large airline scheduling and operational problems as well as modern search engines.

Commentary: Few problems were reported with this section. Following a suggestion of the previous section panel chair, inverse problems have been added to the description; connections with Sections 13 and 14 have also been added.

Section 17. Statistics and Data Analysis (8–11 base lecture slots).

Description: *All areas of statistics, including inference, parametric and non-parametric statistics, together with all branches of mathematics for data science, where data science includes machine learning, signal and image processing, data generation, data representation, and their applications.*
Connections with Sections 2, 5, 8, 11, 12, 14, 15, 16, 18.

Justification: The last couple of decades have witnessed the accelerated impact of statistics and data sciences on fundamental aspects of our society and daily lives. Important algorithmic developments, scalable methodology, numerical experimentation, as well as practical validations and nonparametric modelling from data, are becoming indispensable in most industries and services, as well as across the physical sciences, medicine, engineering, social sciences and the arts.

A broad spectrum of mathematical domains have been shown to offer insights in understanding and exploiting data, including high-dimensional statistics, optimization, information theory, theoretical computer science, harmonic analysis, algebra, geometry, stochastic analysis and probability.

Commentary: This section was formed from components of two previous ICM sections, namely the former Section 12 (Probability and Statistics) and the former Section 17 (Mathematics in Science and Technology). See the commentary on the new Section 12 for the rationale for separating Probability and Statistics from each other. The former Section 17 had significant problems with the sheer breadth and diversity of the section, with the panel reporting substantial difficulty in covering the entire scope of the section, and with little commonality between the talks in the section. On the other hand, the portion of the former Section 17 that involved data analysis had significant synergy with Statistics. We have therefore merged that component of that section with the Statistics component of the former Section 12 to create this new section. In the description and justification, an emphasis is now placed on mathematical methodology, rather than application domain, although we envisage that many of the talks in this section will continue to have close connections to real-world applications. Many of the remaining topics previously covered by Section 17 have now been migrated to Section 15 and the new Section 18.

Section 18. Stochastic and Differential Modelling (4–6 base lecture slots).

Description: *The mathematical development of stochastic and deterministic differential modelling, and applications to such fields as biology, chemistry, medicine, material science, finance, and social network modelling. Deterministic and stochastic systems of any (possibly high) dimension, and at several scales (multiscale modelling). Tools for model reduction, calibration, uncertainty quantification and data assimilation.*
Connections with Sections 9, 10, 11, 12, 15, 17.

Justification: Newton, then Itô, introduced crucial tools for modelling our society as a differential system – and the impact of their work has been extraordinary. The technical richness and diversity of modelling in this space continues to progress at a considerable pace as does its importance to our society. Moreover, important areas of science that have mostly evolved without a rigorous mathematical approach as, e.g., biology and medicine, are today experiencing a tremendous demand for mathematical understanding and provide a major source of mathematical challenges for differential systems. Indeed, the area is one of the largest in terms of publications in MathSciNet.

This section should showcase the most important work in this field. Importance should come from the impact and insight the approach generates inside and also outside mathematics. The section will cover both the modelling and the technical underpinning; it will also include less obvious but important technical extensions (such as hedging, and now rough volatility in finance), as well as more established technique applied to innovative applications.

Commentary: This important and vibrant part of mathematics has been underrepresented at the ICM for historical reasons. Important mathematical contributions in this area have impact in several field of science. Contributions have in the past been partially represented in different sections as 9, 11, 12 and the former Section 17; in contrast, this new section aims at bringing together mathematicians working in very different application domains, but sharing the use of rigorous mathematics as a tool to understand the functioning and operation of nature and society.

Section 19. Mathematical Education and Popularization of Mathematics (2 base lecture slots + 3 panels).

Description: *Range of research and key issues in mathematics education, from elementary school to higher education. Modern developments in effective popularization of mathematics, from publications, to museums, to online communication. Connections with Sections 17 and 20.*

Justification: Mathematics Education and Popularization of Mathematics are domains of interest and responsibility for all mathematicians, and are influenced by both the history of mathematics and cutting edge developments in technology. This section aims to present key issues and research in mathematics education, and new developments in the popularization of mathematics. The two themes are both complementary and supplementary. The range of domains of study in mathematics education are visible across topic study groups in the International Congresses on Mathematical Education (ICME).

Commentary: Few problems were reported with this section, and we have kept the description and justification unchanged (after taking into account the renumbering of some sections). The section panel chair noted that while the education and popularization subpanels worked independently, they cooperated well with each other, especially with the number of slots being fixed in advance. One operational difficulty is that the level of prestige associated to an ICM talk in these communities is not as great as in other sections, and so there were some issues in getting speakers to accept the invitation, or to find replacements for last-minute cancellations. The chair also noted that having diverse members of the panel, such as an editor of the AMS Notices, or a representative from IMAGINARY, was extremely helpful in generating creative suggestions in this panel.

Section 20. History of Mathematics (3 base lecture slots).

Description: *Historical studies of all of the mathematical sciences in all periods and all cultural settings.*

Justification: Mathematics has a history that extends back more than 4000 years and reaches into every culture and civilisation. Research in history of mathematics, which can be done on various methodological, biographical and contextual levels, draws on a diversity of mathematical, philological and cultural sources which require broad general historical and political knowledge as well as specialised technical mathematical knowledge for their interpretation. In recent years, the digitisation of manuscripts and printed texts has opened up new avenues for research in many different directions, and in particular the growing availability and accessibility of sources beyond Europe has helped to stimulate study in the history of mathematics on a global scale. In an age of rapid growth and specialization of mathematics, and the increasing societal importance of mathematics, history can provide tools for reflection and inspiration to practitioners, as well as a means for understanding to the general public.

Commentary: No problems were reported with this section, and we have therefore left the description and justification unchanged. However, the previous sectional panel chair, June Barrow-Green, had some additional suggestions for the next congress in her separate capacity as chair of the Executive Committee of the International Commission on the History of Mathematics (ICHM), which is included in Appendix A.

5. Further recommendations

In addition to our main structural recommendations and revisions to the section descriptions and allocations, the Structure Committee also unanimously make the following less major recommendations regarding various aspects of the Congress (including some that are not within the core responsibilities of our committee).

(1) For the plenary, sectional, and public lectures talks, the speakers should have a subpage in a centralized location of the ICM webpage in which they can upload videos, notes, slides, images, links to papers or tutorials, etc. in advance of the congress, but made available after the talk (together with the video of the talk). Given the increasingly important role of online video in dissemination of these lectures, we encourage the Organizing Committee to ensure that the videos of all talks are of acceptable quality, and made freely available in a timely fashion.
(2) There is an urgent need to bring a new generation of young mathematicians to build bridges between different fields of mathematics and its applications and build a more unified and interactive field in the coming years. The ICM plays a special and valuable role in mathematics, particularly for graduate students, postdocs, and other junior faculty. Accordingly, we ask the IMU to propose to Adhering Organizations that the resources for supporting travel to the ICM should be enhanced for such participants. We also encourage organizations bidding for the ICM to solicit funding for such researchers to attend the congress. (Currently, some funding agencies restrict the use of personal grants to support participation in the ICM, and this results in serious difficulties for senior mathematicians to support the participation in the ICM of early career mathematicians in their research groups.)
(3) Invitees to the Congress who, due to exceptional circumstances (such as medical emergencies, or giving birth too close to the date of the Congress), are unable to attend the Congress in person, should be offered potential accommodations, such as giving the talk remotely or having a designated speaker present the talk in place of the invitee, and should still be officially listed as an invitee of the Congress and given an opportunity to contribute to the ICM proceedings.
(4) In order to monitor the general level of function of the Congress, and in particular the expository quality of the lectures, we recommend an exit survey for participants for the ICM, in order to address such questions as the extent to which participants attended talks outside of their field, and how the ICM could best serve them. We would also ask the Organizing Committee to try to collect some information regarding the approximate level of attendance of each of the sessions. In the next few years, our committee will work on designing suitable questions for this survey.
(5) We suggest that satellite conferences consider adding "special sessions" or "minisymposia" focusing on an interface between two fields of mathematics, such as a pure and applied topic. We encourage the Organizing Committee to seek out such opportunities.

(6) The Structure Committee endorses the efforts of the International Mathematical Union to reach out to the Adhering Organizations and organizations representing under-represented groups to nominate candidate speakers for plenary and sectional talks, and encourages further outreach in this regard, and to explore further creative ideas to showcase the work of mathematicians from these groups at the Congress.

6. Future committee plans

A version of this report will be presented at the next General Assembly of the IMU.

In subsequent years, our committee plans to review the implementation and effect of the proposals made in previous sections of this report, as well as collect feedback from Adhering Organizations, the Program Committee, and other stakeholders, allowing us to make revisions and updates to our recommendations as required. In particular, we will advise the Program Committee on how best to implement the proposed changes to the plenary and sectional lectures, and also suggest appropriate changes to the guidance documents given to that committee. We will also coordinate with the Program Committee chair to contact sectional panel chairs for their input on revising the description and justification of their section.

In 2020 or 2021, the Structure Committee will draft a suggested exit survey for participants of the 2022 Congress, in order to solicit as much valuable feedback as possible to help guide the structure of subsequent Congresses, and in particular to identify outstanding issues that were not fully addressed by the proposals listed here. We also plan to author a short welcome message as part of the orientation packet for the ICM participants, explaining some of the changes we have made to the structure of the Congress and to encourage the participants to contribute to the survey.

In 2019, our committee did not have enough time to properly explore a suitable role for bibliometric data in guiding our suggested ranges of sectional talks, and indeed the only data we had available by the time of our face-to-face meeting was some raw MathSciNet publication count data, sorted by Mathematical Subject Classification (MSC) number, which was problematic to use for a number of reasons. We plan to discuss this issue in coordination with the Committee on Electronic Information and Communication (CEIC), and to obtain more relevant bibliometric data in subsequent years.

Appendix A. Feedback for the Organizing Committee

In the course of surveying participants from the preceding Congress and other stakeholders, we obtained some feedback that did not directly pertain to matters within the jurisdiction of the Structure Committee, but might still be of interest to the next Organizing Committee. We therefore summarize some of that feedback here, without endorsing any proposed action in response, in case that committee wishes to discuss the issues raised.

- The chair of the International Commission on the History of Mathematics (ICHM), June Barrow-Green, wrote "Short Communications session and Posters in history of mathematics were not coherently organised. Some speakers in the session spoke on topics that had nothing to do with history of mathematics with the result that some of the young, very good historians of mathematics, who did speak in the session felt rather isolated and a bit despondent." Barrow-Green further added "As you will know, it is part of the ICHM's remit to be involved in the ICM. At the 2018 ICM we organised a Symposium on the History of Mathematics but there are other things the ICHM could do, e.g. jointly organise a panel discussion with another commission of the IMU, such as the Commission on Developing Countries", and offered to discuss these possibilities further.
- A survey respondent noted that some of the *laudatio* talks for prize winners were not accessible to a significant portion of the Congress audience, and suggested considering inviting *laudatio* speakers who were not as close in area to the laureate, but who could give a more broadly accessible talk. [Note however that in some cases the *laudatio* speaker was chosen by the prize winner.]
- Another survey respondent commented on the generally low quality of the contributed talks, although this could be difficult to solve, since in many cases these talks serve to fulfill a formal requirement by funding agencies to support participation in the Congress.
- A further survey respondent suggested inviting some mathematicians with a good record in popularization of mathematics to cover the Congress (ideally in a variety of languages) from a more "journalistic" perspective, but with an intended audience at the PhD student level rather than to the wider public.
- Several respondents on Tao's blog expressed a desire for more social events, in particular those which would encourage mingling between early career researchers and more established mathematicians. Possibilities include a dinner or lunch with randomized seating, or a poster competition judged by several senior mathematicians.
- Another respondent on Tao's blog expressed the concern that some of the public lectures may have been aimed more at the typical Congress participant than at the level of the lay public, and that given the other activities the public lectures should focus more on genuine outreach to the wider community. The same participant also recommended increasing the visibility of the more applied prizes awarded at the ICM, such as the Gauss and Leelavati prizes.

- The registration fee was seen as excessive by some participants (particularly those from developing countries).

Appendix B. Feedback for the Program Committee

As a further component of our information gathering process, we contacted the sectional panel chairs of the previous ICM. Several of these chairs made operational comments about their Program Committee which were not strictly within the jurisdiction of our own committee, but may still be raising issues of interest to the next Program Committee. As with the feedback in the previous section, we report on some of this feedback here, again without endorsing any proposed response.

- One sectional panel chair wrote "I felt the process [for negotiating joint speakers between sections] wasn't as cooperative as it could have been – the different panels were quite competitive about slots. Also our panel was further ahead in the process than most of the other panels, which made discussions difficult... Also the process for selecting cross panel speakers was a bit unclear. I had understood that we had to agree with another panel, but at the end of the process we found speakers added to our section which our panel had explicitly rejected in direct talks with other panels. I had not realized that we could 'appeal' to the program committee if other panels rejected our joint speaker suggestions... Probably a more muscular role for the program committee is the right way to go, but it should be made clear to the panels that they can suggest joint speakers to the program committee even when the other panel turned down the idea." However other chairs reported the negotiation process to be smooth or mixed (the latter due to varying levels of cooperation with other sectional panel chairs).
- The previous Program Committee Chair made significant efforts to stay in frequent communication with the sectional panel chairs, by face-to-face whenever possible, and this was appreciated by several chairs. However, other chairs felt that they were not consulted on some sensitive issues, for instance when a candidate explicitly rejected by a section was added back by the Program Committee, or when a candidate too close to one of the committee members (e.g., a former student) was added (though the Program Committee chair did note there was also the opposite problem of some sectional panel members arguing quite forcefully for people closely affiliated with them). One chair expressed frustration at being forced to sign on to such changes by the Program Committee.
- Several sectional panel chairs reported difficulties in obtaining an appropriately diverse committee and list of speakers, with one chair noting the possible tension between the pressure to ensure geographic diversity of speakers and the need to maintain the highest level of quality of the speakers.