European Mathematical Society Magazine
ISSN 2747-7894 / Issue 133 / September 2024

EMS Magazine

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EUROPEAN MATHEMATICAL SOCIETY

European Mathematical Society Magazine

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Published by EMS Press, an imprint of the
European Mathematical Society – EMS – Publishing House GmbH
Technische Universität Berlin, Institut für Mathematik,
Straße des 17. Juni 136, 10623 Berlin, Germany

https://ems.press

Typesetting: Tamás Bori, Nagyszékely, Hungary
Printing: Beltz Bad Langensalza GmbH, Bad Langensalza, Germany

ISSN (print) 2747-7894; ISSN (online) 2747-7908

The cover illustration is a portrait by António B. Araújo of Michel Talagrand, who was awarded the Abel prize in 2024.

Photo by Jim Høyer, University of Copenhagen.

It has been a very busy and active summer for the EMS. We first had our council in Granada and then the European Congress of Mathematics, the 9ECM, in Seville. I hope many of you were there in Seville. It was a great congress with a great many opportunities to celebrate mathematics and mathematicians and to discuss issues related to all aspects of the field across many panels. The congress was extremely well planned and on behalf of the EMS I want to thank the local organizers, in particular Juan González-Meneses and Isabel Fernández, for the enormous effort that went into making this such a successful event. If you were not in Seville, I encourage you to look at the list of events and recorded talks available online, a testimony to our thriving field.[1]

One of the more enjoyable moments I've had as the president of the EMS was the opportunity to present the prizes at the European Congress. I want again to congratulate all this year's prizewinners:

The ten EMS prizes went to *Maria Colombo, Cristiana De Filippis, Jessica Fintzen, Nina Holden, Tom Hutchcroft, Jacek Jendrej, Adam Kanigowski, Frederick Manners, Richard Montgomery,* and *Danylo Radchenko*.

The Felix Klein Prize went to *Fabien Casenave*. The Otto Neugebauer Prize went to *Reinhard Siegmund-Schultze*. The new Paul Lévy Prize in Probability Theory went to *Jeremy Quastel* and the new EMS/ECMI Lanczos Prize for mathematical software went to *MUMPS (MUltifrontal Massively Parallel sparse direct Solver): Patrick Amestoy, Jean-Yves L'Excellent,* and *Theo Mary*.[2]

The council in Granada, which took place before the congress, was a fruitful opportunity for the Executive Committee of the EMS to discuss with its delegates and get productive feedback on the work of the EMS. There were several interesting discussions, and the Executive Committee has many issues to think about after the Council. The Council elected three new members to the Executive Committee, and I want to welcome Maria Ángeles García-Ferrero (who is also a representative of EMYA, the EMS Young Academy), Adam Skalski, and Alain Valette as new members of the EC. I am greatly looking forward to working with them. They will be replacing Beatrice Pelloni, Frédéric Hélein, and Luis Narváez Macarro at the end of the year. Frédéric and Luis have decided to retire from the EC after their first term. Beatrice will have served her two terms and is currently serving as vice president as well. As Beatrice, Frédéric, and Luis are still on the EC until the end of the year, so it is too early for us to say goodbye. The council elected the current EC member Victoria Gould to replace Beatrice as vice president from 2025. Vicky has been a very engaged member of the EC and a unanimous EC nominated her for the vice presidency. I am happy that the council took this decision, and I am confident that Vicky will be an excellent vice president and will be devoting a lot of energy to the EMS, as she has already done. I am very happy that the council also reelected Barbara Kaltenbacher and Susanna Terracini to their second term on the EC.

I mentioned in my last message that in our efforts to make EMS a more professional organization we have decided to hire a community engagement manager who will be responsible for all the communication channels of the EMS and for our grant application procedures. It is my great pleasure to welcome Enrico Schlitzer as the new Community Engagement Manager. Enrico has a PhD in mathematics from SISSA in Trieste and a master's degree in science communication. Moreover, Enrico already has a lot of experience with science communication. His position is part-time, and he will be working 75% for the EMS and 25% for the EMS Press. Enrico started his position just before the summer, and he is already implementing many new ideas. You may have already met Enrico during the 9ECM; if not I am sure you will all be hearing a lot from him in the future.

Let me finally congratulate Donatella Donatelli with this being her first issue of the EMS Magazine as our new editor-in-chief.

I unfortunately have to end this message on a sad note. The former president of the EMS Rolf Jeltsch passed away on June 28, 2024. Rolf was the president of the EMS from 1999 to 2002. Rolf was a visionary president and did a lot for the EMS. In particular, he was instrumental in establishing the publishing efforts of the EMS, which eventually led to the creation of our successful EMS Press. You can read more about Rolf Jeltsch in the obituary by Volker Mehrmann in this issue of the Magazine.

Thanks so much to all of you who participated in the Council or the 9ECM, and in general to everyone for your involvement in the EMS. With all good wishes for a new academic year,

Jan Philip Solovej
President of the EMS

[1] https://www.ecm2024sevilla.com

[2] You can find all the details and the citations here: https://euromathsoc.org/news/fourteen-prizes-awarded-to-european-mathematicians-at-the-9th-ecm-121.

Dear readers of the European Mathematical Society Magazine,

It is my honour, a challenge and a great responsibility to accept the invitation of the Executive Committee of the EMS and of its president, Jan Philip Solovej, to become from 1 July 2024 onwards the editor-in-chief of the EMS Magazine.

The previous editor-in-chief, Fernando Pestana da Costa, under whose guidance I had the privilege of working as an editor for the book review section for the past three and a half years, has done a really superb job in managing and promoting the EMS Magazine and enhancing its relevance for the European mathematics community. I am grateful for his patience and the instructive and attentive way he guided me through the steps of the production process in this handover and for his wise suggestions on how to run the journal.

The EMS Magazine is in a very good shape and attracts the attention of readers within as well outside Europe. I shall do my best to keep its high standards and reputation. The EMS Magazine has an editorial board of very motivated and active people, and with the aid of the EMS Press staff I am optimistic that we can keep bringing to your attention insightful perspectives on research, news and other items of interest in mathematics in progressively better ways.

At the end of this editorial I want to quote David Hilbert (1862–1943): *"Mathematics knows no races or geographic boundaries; for mathematics, the cultural world is one country."* My purpose is to ensure that the EMS Magazine will continue to be this *one country for the cultural world*.

Therefore, I conclude this editorial with the final words of the editorial by Valentin Zagrebnov in Issue 101, when he became editor-in-chief, and repeated also in Issue 117 in the editorial by Fernando Pestana da Costa, when he became editor-in-chief *"We hope that all readers will feel free to contact the editorial board whenever they have ideas for future articles, comments, criticisms or suggestions."*

Donatella Donatelli
Editor-in-chief

Every file is a program, but not the reverse

English translation of the article entitled "Tout fichier est un programme… et non l'inverse" and published in *La Gazette des Mathématiciens* **176** (April 2023)

Baptiste Mélès

The concept of a program, unlike that of a file, is an informal one, giving rise to inaccurate or even false assumptions. In this article, we will contest two of them. First, using historical examples, we will show that there are programs that are not files. Then, more surprisingly, we will argue that any file can be seen as a program, since all criteria characterizing programs hold true for files. In particular, we will conclude that there is no technical reason to distinguish between file/program and program/interpreter pairs.

1 Introduction: technical vs. informal concepts

Since scientific discourse does not rely exclusively on technical concepts, it leaves certain questions to philosophy.[1]

By technical concepts, we mean those that have a precise definition enabling their exact usage within the internal framework of science, i.e., a definite attribution to certain objects, their according usage in justification procedures – demonstration, observation, experimentation – and finally in scientific statements; this is the case for the concepts of integer, derivative, electron, mammal, zero-sum game, etc. The definitions of technical concepts are always precise, backed up by methods for verifying whether they can be applied to objects.

The same cannot be said of certain more informal concepts which, at the frontier between science and common experience, are suited to approximate usage, such as the concepts of number, calculation, living, etc. In the absence of an exact definition, these are generally too approximate or too slippery for scientific use. Whenever an attempt is made to provide these informal concepts with a rigorous definition, it will always be open to discussion.

It is true that scientists sometimes propose a rigorous definition of a hitherto informal concept; but whether the proposed definition correctly and completely translates common intuition remains an open question, belonging to philosophy rather than science. So, when Gentzen calls his formal system of logical deduction a "natural deduction," when Turing claims that his machines can compute everything and not only what is ordinarily called "computable," both are developing technical concepts based on the prior analysis of informal concepts [3, 4, 12]: a philosophical approach, not a scientific one. Scientific theories of proof and computability can then be developed on this basis, but the philosophical debate will continue on the starting point, namely the definition of what it means to deduce naturally and what it means to compute.

Indeed, the study of informal scientific concepts in their relation to technical concepts calls for properly philosophical methods such as conceptual analysis and dialectical discussion, if by the latter we mean the contradictory examination aimed at gaining knowledge of things beyond their first appearance. Thus, for example, in a famous article, James H. Moor showed that three conceptual oppositions commonly found in computer discourse – software and hardware, digital and analogue, model and theory – did not in fact correspond so much to distinct entities but rather to different ways of looking at the same thing [9]. The informal concepts used in scientific discourse call for philosophical methods.

It is precisely at this frontier between sciences and philosophy that we will study the relationship between two central concepts of computer science: file and program.

2 What you may have heard about programs and files

Let us first define the terms "file" and "program," before summarizing what one commonly assumes one knows about them.

The term "computer file" is a technical term, and as such, is susceptible to precise definition. A file is a sequence of binary digits (bits) denoted in a computer system by an identifier – typically a name or a number.[2] One distinguishes between plain text files

[1] Of course, this does not mean that philosophy cannot *also* have its say on technical concepts.

[2] The Multics designers define a file as follows: "A file is simply an ordered sequence of elements, where an element could be a machine word, a character, or a bit, depending upon the implementation" [1]. Andrew Tanenbaum suggests the following definition: "A Unix file is a sequence of 0 or more bytes containing arbitrary information" [11]. However, a more technical definition of "file" is simply that it contains source code, according to the Unix source code `inode` structure [6, lines 5659–5675].

(conventionally given the extension `.txt`, …), word-processing documents (`.odt`, `.doc`, …), spreadsheet documents (`.odc`, `.xls`, …), audio files (`.ogg`, `.mp3`, …) and video files (`.mpg`, …), as well as directories and some "special files," which under Unix family systems denote printer, screen, scanner, processor temperature and so on [10, p. 367] and [2].[3] This precise definition makes it technically easy to determine whether a given object is a file.

The concept of a program, however basic it may seem in computer science, is an informal one. We can, of course, propose formal interpretations of it, typically dependent on an arbitrarily chosen computational model: a program will sometimes be defined as a term of the λ-calculus, sometimes as the set of transitions of a Turing machine starting from an initial state, and so on. But these concepts do not characterize what a program is: they simply attest that λ-terms or Turing machines can be seen as programs, and that any program could in absolute terms be seen as the analogue of a λ-term or a Turing machine… *albeit with some translation*. But when one calls a C-language source code a "program," one is not thinking about λ-terms, and one is convinced that we are in the immediate presence of a program.

So what does one usually think of as a program? We consider that a common-sense definition of a program is *a layout of symbols that is supposed to determine the behaviour of a machine*? [4]

Like any real definition, this definition requires a few explanations. First, we will say that a program is a "layout of symbols" in general, since it can be a chart, a diagram or a punched card, as well as a text made up of letters and other typographical symbols. The "machine" itself can then be situated in a particular environment made up of human actors as well as physical objects and other machines. Finally, the program is only "aimed" at determining the expected behaviour because, as the etymology indicates, the program is *written before* it is executed, and it can also be faulty yet still be a program. We will not use the notion of programming language, as it would be perfectly tautological to define a program as something written in a program-writing language.[5] Our current aim would be achieved if our definition were not deemed too contrary to common sense.

Now let us look at what one generally assumes to be obvious about programs. They would be texts written in a "programming" language; they would intrinsically consist of a sequence of instructions, which enables them to be executed; being composed of "instructions," they would be intrinsically active objects. In all this, they would be opposed to *data*, which are inert objects, containing no instructions and only playing a role in an active process when passed as an argument to a program; they would therefore be intrinsically passive. A special case of data are the *files*, which can be passed as input to a program, but which in most cases are not programs, given that they do not contain instructions enabling them to be executed by a system.

The following two theses will be widely shared:

1. Judging by the programs that populate our hard disks, *all programs are files*.
2. A few trivial examples, such as plain text files and audio files, demonstrate that the reverse is not true; in other words, *not all files are programs*.

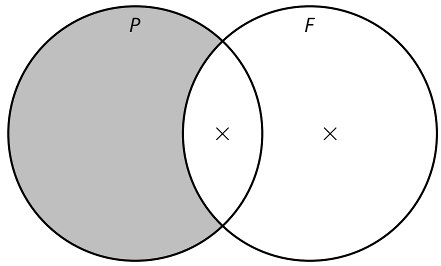

Figure 1. The relation between file and program according to common sense.

We will show that these two common-sense assertions do not stand up to technical scrutiny, which will lead us to the following two theses:

1. Not all programs are files.
2. All files are programs.

3 Not all programs are files

In today's computer practice and culture, we might be tempted to support the first common-sense thesis, according to which *every program is a file*. In support of this thesis, we can invoke the following *intuitive argument*: all we have to do is look in our hard

[3] For a philosophical analysis of what is a file in UNIX, see [8].

[4] A similar intuition is, e.g., expressed in Clarisse Herrenschmidt, *Les Trois écritures : langue, nombre, code*, Paris, France, Gallimard, 2007, p. 404: "Qu'est-ce qu'un programme ? Un programme est un texte où sont consignées les instructions données à un ordinateur, un texte écrit dans un langage." (What is a program? A program is a text in which the instructions given to a computer are recorded, a text written in a language. [Our translation])

[5] That is what the ISO does by defining a program as a "syntactic unit that conforms to the rules of a particular programming language and that is composed of declarations and statements or instructions needed to solve a certain function, task, or problem"… before defining "programming language" as an "artificial language for expressing *programs*?" [our emphasis]. It is also worth noting that this definition omits the concept of the machine, which seems essential to us (International Organization for Standardization, 2015: Information technology – Vocabulary. (ISO/?IEC Standard 2382:2015(en)), https://www.iso.org/obp/ui/#iso:std:iso-iec:2382:ed-1:v2:en, accessed 06/15/2022).

disks, and we'll see that all the programs we can find there are files, whether binary files or scripts, i.e., text-mode program files intended for mechanical interpretation.[6]

However, this argument is not sufficient to prove this thesis, for two reasons.

1. The argument is based on an improper generalization. It is based on experience, which always allows us to form existential theses, but never – except in the finite case – universal theses. Since one cannot conclude from the existential affirmative to the universal affirmative, one can derive from experience the statement "some programs are files," but not "all programs are files."
2. The argument is circular. The experiment in question implicitly assumes the context of programs found in our modern computers, where programs happen to be stored in a memory structured by… a file system.[7] If we make this context explicit in the above formula, we obtain the following tautology: "Every program *file* is a *file*."

Let us go a step further and refute not only the intuitive argument, but the first common-sense thesis itself: history attests to the existence of programs that were not files. File systems did not appear until the 1960s, with the CTSS and Multics operating systems [1], even though programs already existed: a punched card from a Jacquard loom, a barrel organ or, more recently, a batch-processing machine is a program, but not a file – not even in retrospect, since it is not part of a file system. The programs that Turing supplies to his universal machine in the form of a "standard description" – e.g., the program
`;DADDCRDAA;DAADDRDAAA;DAAADDCCRDAAAA;DAAAADDRDA;`
which alternates between 0 and 1 – are not files either. So, against the first common-sense thesis, we can assert that *not all programs are files*.

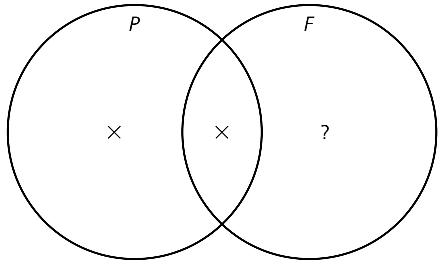

Figure 2. Not all programs are files.

4 All files are programs

Let us turn now to the second common-sense thesis, according to which *not all files are programs*, or in other words, *some files are not programs*. Like the previous one, this thesis can be based on an intuitive argument: videos, text files, etc. are indisputably files, but they are not programs.[8] This time, the empirical argument is safe from any improper generalization, since a single example suffices to demonstrate an existential thesis.

However, against this intuitive argument, we are going to show that every file is a program. We will do this by analysing successive file types, from the most obvious to the most general case: first, we will study the trivial case of *program files*, in order to reveal by which criteria we judge a file to be a program; then we will take a closer look at *data files* to show that these criteria apply just as well to them. In other words, if the former are programs, then the latter should be too.[9]

4.1 Why are program files programs?

Why wasting time demonstrating such a trivial thesis as *program files are programs*? Because what we are interested in here is not simply revealing *that* this thesis is true, but rather *what makes* this thesis true: we will see later that these criteria, once admitted, actually apply far beyond these obvious cases.

[6] Generally speaking, it is difficult to provide references for common-sense theses: theses that are taken for granted have virtually no author. One example among a thousand, no more representative than any other, is a text signed under the pseudonym StackLima, entitled "Différence entre programme et fichier" (Difference between program and file [our translation]) and dated 07/05/2022 (URL: https://stacklima.com/difference-entre-programme-et-fichier/; accessed 10/28/2022), stating the following definition of programs [our translation, our emphasis]: "Programs, as their name implies, are simple executable *files* containing a set or collection of instructions used by the computer to execute or perform particular tasks and to produce desired results." It must be stressed that we are not dealing here with a scientific text, which explains and even excuses its many inaccuracies.

[7] A file system (e.g. FAT32, NTFS, ext4, etc.) is a device for structuring computer memory into files, i.e., sequences of characters. This device specifies the memory segmentation mode, data structures for referencing files, an overall topology (typically a tree structure), file manipulation functions (creation, deletion, modification, dating, etc.) and various other functions (logging, rights management, encryption, network adaptation, etc.).

[8] The text on the difference between program and file quoted above distinguishes in two columns the supposedly distinct characteristics of programs and files. On one of the lines, we read the following two sentences, implicitly presented as an opposition [our translation]: "Program types include application programs, system programs such as word processors, operating systems, database systems, etc. File types can be JPEG, PNG, GIF, PDF, MP4, etc." With this reference, we simply intend to illustrate an informal opposition between programs and files that seems to us to be fairly widespread.

[9] We are not denying a difference in nature by arguing a difference in degree: we could just as easily have gone straight to the last case, which is the most general; however, for pedagogical purposes, we have opted for a more progressive approach.

We will treat three types of program files, from the simplest to the less obvious: (a) binary files, (b) files to be compiled, (c) files to be interpreted.

Because they are machine-executable

The most obvious type of program is the binary program file.

A binary program file is a sequence of instructions in machine language, i.e., directly interpretable and executable by the machine without any intermediary. It is made up of sequences of 0s and 1s, and is generally not displayable in text form: if you try to display it, you will generally get a mindless succession of strange symbols – graphic symbols, emoticons, punctuation marks, characters of all alphabets and even signs that cannot be viewed because they have no equivalent in ASCII or Unicode coding.

Clearly, any binary program file trivially satisfies what we consider as the common-sense definition: "a layout of symbols aimed at determining the behaviour of a machine." The machine executes this program directly, and it is written in the very language of its processor.

We have got a first conclusion to draw from this: Anything that can be directly executed by the machine is a program.

Because they are translatable into executables

However, not all programs can be directly executed by the machine. What makes them programs nonetheless?

Let us look at the case of program files to be compiled. A binary program file is often produced from a text file written in a so-called "programming language" such as C or Java. Here is a short classic example of a program file to be compiled, written in C:

```
#include <stdio.h>

int main()
{
    printf("Hello world.\n");
    return 0;
}
```

Can we say that program files to be compiled are programs in the same sense as binary program files? Common intuition does not put this in doubt: it is not uncommon to say "my program" when referring to what is in fact only the *source code* of a binary program. The only difference with binary program files is that the program files to be compiled do not directly modify the behaviour of the machine: they do it only after a translation stage, called compilation.

This leads us to the following thesis: a file can be a program, *even if it is not directly executable and its execution presupposes a prior extrinsic step*.

This concession is important, as it shows that a program is not always an *intrinsically* active object. A compilable program is merely a text file which, in order to become active, must be supplied to another program. The above-mentioned common conception of programs and data, as opposed to one another, proves thus to be wrong: some data turn out to be programs if there is a suitable translator. In at least some cases, it is a condition extrinsic to the program file itself – the existence of the compiler – that turns the file into a program. *The opposition between programs and data is therefore not intrinsic.*

It may be objected that, *once compiled*, the file is transformed into a binary program, making it "directly executable" by the machine. A compilable file is, in this sense, "indirectly directly executable."

Because they can be interpreted as executables

However, program files are not restricted to binaries and compilables: one also commonly groups interpretable files in this category.

An interpretable program file is a program that is intended to be executed as it is read by a specific program. Shell scripts are interpreted by a shell, batch files by MS-DOS, Perl, Python etc. scripts by the respective interpreters of these languages, and so on. Here is an elementary example of a shell program:

```
#!/bin/zsh

for nephew in Huey Dewey Louie
do
    echo "Hello $nephew!"
done
```

Can we say that interpretable program files are programs in the same way as binary or compilable program files are? Unlike binary or compilable program files, interpreter program files do not directly modify the behaviour of the machine, even after an intermediate step: they modify the behaviour of an intermediate program that is currently running, namely the interpreter. But since the interpreter is itself running, any change in its behaviour modifies the behaviour of the machine. The program files to be interpreted, which common intuition calls programs, therefore always respect our definition of a program as "a layout of symbols aimed at determining the behaviour of a machine."

The following thesis can be drawn from this: a file can be a program *even if it requires the execution of an intermediate program to modify the behaviour of the machine*.

The files in this class qualify as programs only in an entirely indirect way, since at no point are they transformed into directly executable files. Their program status is – and remains – purely extrinsic, since it depends on the existence and execution of the specific program, namely the interpreter.

Conclusion: the high price of a trivial thesis

Analysis of these three trivial cases – binary, compilable and interpretable programs – leads us to the unsurprising conclusion that *program files are programs*. But this assertion is not without concessions, since we have to admit that a program may not be directly executable by the machine – as compilables prove – and may even never be transformed into a machine-executable file – as interpretables prove. There is a certain price to pay for adhering to this seemingly trivial thesis.

We will now show that this apparently obvious thesis opens a Pandora's box: Any file can be seen as a program.

4.2 Why not consider data files as programs, too?

While it is easy to admit that program files are programs, in the case of data files this thesis seems not only less obvious, but downright false. Yet we are going to demonstrate that everything that classifies program files as programs also applies to data files.

Again, we will proceed in three stages, from the simplest to the least obvious, successively examining (a) document files to be compiled, (b) structured data files and (c) any files.

We will first show that not every compilation produces an executable; then that any structured data can also be seen as an instruction; finally, that any data can be seen as structured, in other words as an instruction.

Not every compilation produces an executable

A document file to be compiled is a file written in a language that allows it to be automatically translated into a file of a given format, which is generally not intuitively recognized as a program. This is the case, for example, with a TeX – not LaTeX – file as the following one, from which one can obtain a viewable or printable file in DVI, PS or PDF format:

```
Hello, {\it world}!
\bye
```

The resulting PDF file is generally not considered a program. But what about the TeX file it comes from?

A document to be compiled like this one contains mainly text – in this case "Hello" and "world" – but also instructions, such as the italics command `\it`, which will be graphically translated into italics in the compiled document, or the `\bye` command, which indicates to finalize the document. So it is immediately obvious that compilable documents contain at least some instructions – just like program files.

Perhaps someone will argue that these files "mix" instructions with simple data? That would be a mistake. The instructions indicated in TeX by a backslash are only one small part of the iceberg: the documents to be compiled are *entirely* made up of instructions. As Donald Knuth pointed out in the TeX language manual, even the smallest letter is a command [5, p. 267]. After explaining that any occurrence of the letter *b* in a TeX document can be replaced by the command `\char98`, Knuth reveals that this is actually TeX's underlying mechanism: it interprets the letter *b* as an alias for this command. TeX simply reads a document as a sequence of instructions. The words "Hello" and "world" are likewise sequences of instructions. TeX is in fact a particularly powerful language, since it is Turing-complete: Anything that can be written in any programming language can be written in TeX – which does not mean it would be a good idea to do so.

So, can we say that compilable documents are programs? As a sequence of instructions, they determine the machine, via compilation, to produce a certain file. This leads us to admit that a document to be compiled is a program *even if it is not written in a so-called "programming" language, and its output is not generally considered to be a program*.

All structured data is an instruction

Let us now consider the case of interpretable document files. We refer to structured documents, i.e., files written in a document presentation language such as HTML, roff, Markdown or SPIP. Here is a very basic example of an HTML file:

```
<html>
    <head>
        <title>HTML page</title>
    </head>

    <body>
        <p>This is an HTML page.</p>
    </body>
</html>
```

A structured document contains not only text, but also instructions such as <body> and <strong>. These commands are interpreted by the browser, just as LaTeX compiles the `\it` instructions and the shell interprets the `echo` command. Even "purely textual" parts such as the words `This is an HTML page` are instructions for the program responsible for displaying it. So if *interpreted programs* (e.g., shell scripts) and *compiled documents* (e.g., TeX files) are programs, then *interpreted documents* are programs in two respects. An HTML file is a program for browsers, a PS file is a program for printers, and even PDF, video, etc. files are programs for viewers of various kinds.

This thesis is worth emphasizing, as it is probably here that common sense will put up the most resistance. According to ordinary intuition, there are data, programs and interpreters; the first are generally not the second, and the second are generally not the third. Yet what we see from the case of structured files – which by definition always obey a syntax no less rigorous than that of program files – is that *a structured file supplied to a program does not technically differ from a program supplied to an interpreter*.

We can thus conclude that not only the texts written in a so-called programming language are programs, but also any text written in a given syntax, even if it is a "document structuring" rather than a "programming" language.

All data is an instruction

Let us turn now to plain text documents, i.e., files that encode a simple sequence of characters, as for example the following text file named `aeneides.txt`:

Arma virumque cano, Troiae qui primus ab oris
Italiam, fato profugus, Laviniaque venit
litora, multum ille et terris iactatus et alto
vi superum saevae memorem Iunonis ob iram;
multa quoque et bello passus, dum conderet urbem,
inferretque deos Latio, genus unde Latinum,
Albanique patres, atque altae moenia Romae.

Any plain-text document opened in any program, even a simple text editor, qualifies as a program for this interpreter. It is structured data – even if it is at the zero level of structure, reduced, for example, to its encoding – and as such it is an instruction in its own right. For example, the file `aeneides.txt` represents the following sequence of instructions for a text editor, or for any other program that is supposed to manipulate it (display with the `cat` command, search with `grep`, etc.): display "`A`," display "`r`," display "`m`"... just as an HTML file without italics is a program interpreted by the browser. Any plain text file, *provided it can be opened by any program*, is consequently an interpreted program in its own right.

It is now easy to move on to the general case of any file: Any sequence of bits, whether readable in text mode, behaves like a program as long as it is supplied as input to a given program, which in turn behaves like an interpreter. Every file therefore respects the intuitive definition of a program as "a layout of symbols aimed at determining the behaviour of a machine." All that is needed is at least one user mechanism – whether a machine or a running program – which adapts its behaviour to the contents of the file.

Before being opened, a file is only potentially a program, but this is also the case for interpretable files. To take such reasoning to the limit, only a file that is not intended to be opened at all might not be a program. We dare to claim – albeit without proof – that there is no such case.

5 Conclusion: An extrinsic characterization of programs

Contrary to the common intuition that all programs are files, but some files are not programs, we have argued that some programs are not files, but that all files can indifferently be considered as programs.

Indeed, we have shown that a program is not necessarily directly executable by the machine, that it does not even always enable the production of a directly machine-executable file, and that it sometimes depends on the underlying execution of another program. The result is that any data file supplied as input to a program can be seen as a program supplied to an interpreter, without there being any technical way of distinguishing the two situations.

A program is therefore not defined intrinsically: What characterizes it as such is a context of execution and use, which is extrinsic to it.[10]

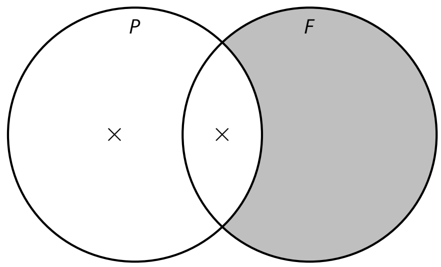

Figure 3. The connection between file and program as defended here.

6 Discussion

Perhaps these conclusions will seem to be counter-intuitive. It will then probably be necessary to develop a more restrictive definition of the concept of program than the one we used.

One option might be to require that a program be written in a "programming language," a concept that will have to be defined in its turn – obviously without circularly appealing to the concept of program – so as not to reopen Pandora's box.

(a) Will we define a programming language as a complete language in the Turing sense, i.e., capable of expressing any algorithm computable in a Turing machine? We will have to justify the heterodox exclusion of Coq, a deliberately incomplete language that admits only the strict subset of the class of terminating functions.

(b) Should we call any language that tolerates recursion a programming language? In that case, we would have to accept the inclusion of all TeX files, since the TeX language offers all the control structures common to programming languages. Conversely, we would have to exclude the Catala language, developed by Denis Merigoux to formalize the French Tax Code, which does not have a general recursion structure [7, p. 11].

[10] A corollary of this conclusion is that the same file can be used for several programs at the same time. An empty file, i.e., of length 0, for example, is both a program for a text editor and for interpreters such as Shell, Perl, Python, etc. A C source code, for its part, causes different machine behaviour depending on whether it is submitted to a compiler – which will produce a binary program file – or to a text editor – which will produce a text display.

Pending a better definition, we will have to accept that there is no technical criterion for distinguishing the file-program pair from the program-interpreter pair, and that their distinction depends solely on the context of use and the purposes of the agent who manipulates them.[11]

Acknowledgements. The *Magazine of the EMS* thanks *La Gazette des Mathématiciens* for authorisation to republish this text, which is an English translation of the paper entitled "Tout fichier est un programme… et non l'inverse" and published in *La Gazette des Mathématiciens* **176** (April 2023). The author thanks J.-B. Bru and M. Gellrich Pedra for the English translation.

References

[1] R. C. Daley and P. G. Neumann, A general-purpose file system for secondary storage. In *Proceedings of the November 30–December 1, 1965, Fall Joint Computer Conference, Part I*, pp. 213–229, ACM, New York, USA (1965)

[2] O. Daudel, */proc et /sys*. O'Reilly, Paris, France (2006)

[3] G. Gentzen, Untersuchungen über das logische Schließen. I. *Math. Z.* **39**, 176–210 (1935)

[4] G. Gentzen, Untersuchungen über das logische Schließen. II. *Math. Z.* **39**, 405–431 (1935)

[5] D. Knuth, *The TEXbook*. Addison–Wesley, Reading, MA, USA (1984, 1996)

[6] J. Lions, *Lions' commentary on Unix, 6th edition with source code*. Annabook, Poway, CA, USA (1996)

[7] D. Merigoux, N. Chataing and J. Protzenko, Catala: a programming language for the law. In *Proc. ACM Program. Lang.*, vol. 5, article no. 77 (2021)

[8] B. Mélès, Unix selon l'ordre des raisons : la philosophie de la pratique informatique. *Philos. Sci.* **17**, 181–198 (2013)

[9] J. H. Moor, Three myths of computer science. *Brit. J. Phil. Sci* **29**, 213–222 (1978)

[10] D. M. Ritchie and K. Thompson, The UNIX time-sharing system. *Comm. ACM* **17**, 365–375 (1974)

[11] A. S. Tanenbaum, *Modern operating systems*. (2nd. ed.), Prentice Hall, Upper Saddle River, NJ, USA (2001)

[12] A. M. Turing, On computable numbers, with an application to the Entscheidungsproblem. *Proc. London Math. Soc. (2)* **42**, 230–265 (1936)

[11] This text was written in the context of the ANR program *What is a program? Historical and philosophical perspectives* (PROGRAMME, ANR JCJC, ANR-17-CE38-0003-01, 2018–2022). It was greatly enriched by discussions with the project leader, Liesbeth De Mol, and Henri Stéphanou, as well as by comments from the rapporteurs of the *Gazette des Mathématiciens*.

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Abel interview 2024: Michel Talagrand

Bjørn Ian Dundas and Christian F. Skau

Bjørn Ian Dundas / Christian F. Skau: *Professor Talagrand, first we want to congratulate you with being awarded the Abel Prize for 2024 for your "groundbreaking contributions to probability theory and functional analysis, with outstanding applications to mathematical physics and statistics." You will receive the prize from the crown prince of Norway tomorrow.*

Michel Talagrand: Thank you.

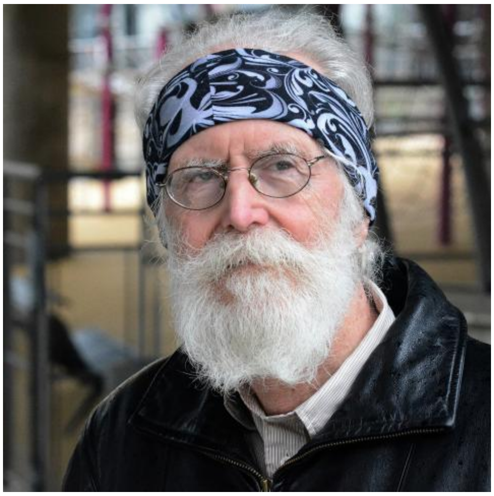
[BID/CFS]: *You've commented that you've had a career like a Brownian motion – a succession of decisive shocks – and let's start at the beginning.*

You were born in 1952, and grew up in Lyon. Your grandparents came from large, poor families in South-Eastern France, but managed to give both your parents a good education. But even though your mother was a French language teacher, as a child you didn't start out on your "improbable academic journey towards probability" as a great student. As far as we understand, you were … well, your French spelling was horrible. How would you describe your childhood?

MT: It was a really very happy childhood. I grew up in an upper class neighbourhood. It was really nice, except that I had a little health problem. I lost my right eye at age five, and this was sort of looming over my life. I didn't do sport at school. But I was not really handicapped.

Things were happy, essentially, until I got 15, and I was in high school. Then I got retinal detachment in my remaining eye. That was a very, very difficult period for me. Medically I survived because the damage was not great, but the psychological damage was really deep. I really lived in terror of becoming blind for years. To fight the terror I had to do something, and that something was to study mathematics, because my father was a maths professor and naturally attracted me there. And why mathematics? Because in all the rest I was very mediocre, including spelling. So it was an obvious choice.

[BID/CFS]: *But you did have a budding interest in that direction already?*



Michel Talagrand, Abel Prize laureate 2024.
(© Peter Badge / Typos1 / The Abel Prize)

MT: I was interested in science from an early age, and again thanks to my father, who subscribed to a scientific magazine. Science was very much in the air, you know. That was the year of the Sputnik. The times were changing, nobody believed that Sputnik would come anytime soon. And then it came. We believed in unlimited progress. That was very naive, but that's what we believed in and science was the natural place where things were happening.

[BID/CFS]: *Then you had this traumatic experience with your eye problem when you were 15, and your father helped you get through it.*

MT: My father helped me greatly. When I was in hospital he went to see me every day, and he talked mathematics to keep me busy and to give me a goal. It had a great effect. You see, somehow I could say that I'm sort of lucky because I had this trouble, which gave me some psychological impetus in a very positive direction. But on the other hand, my eye damage was not so bad. I could function properly. I could, okay, with some limitation, function, and it was not an impairment in my life. While on the psychological side – in spite of the terror of becoming blind – it was a great positive, so overall I benefitted from that. I probably would not have become a mathematician, if I didn't have this health problem. I'm sure.

[BID/CFS]: *Part of that time your eyes were bandaged, right?*

MT: You know, medicine has made a lot of progress in treating retinal detachment, but at the time I had to stay in bed for months with the eyes bandaged. And my father came every day and talked to me. He explained to me integration by parts, you know, I remember that. And I felt so good, I could understand something. This is how I learned the power of abstraction.

[BID/CFS]: *You say you had very competent high school teachers.*

MT: I was in the best high school in Lyon, where my father was a professor. And the last two years there were remarkable high school teachers. The French system has a very demanding certification method for people who are teachers in the last two years of high school, and they get fantastically good results. My maths teachers in the last two years were both great, the physics teacher was great and the natural science teacher was great. It's really amazing how good these people were.

I can tell you a funny story. I was complaining to my maths teacher in the last year of high school that the exams were too easy. So she would add bonus questions just to keep me happy, essentially. And she encouraged me. And I felt good.

[BID/CFS]: *Last year of high school you participated in the Concours Général, a French Olympiad for top high-school seniors. How did that go?*

MT: I ranked third nationally, both in maths and physics. While I felt happy to win such an award, I didn't attach much importance to it. The French system is, I think, a greatly efficient system. But I could not really take advantage of it, because my parents felt it was too demanding considering my health problems. So I went to the university instead, which is not the royal road in the French education system. The best track for higher education in France is to attend special schools (the grandes écoles, like École Normale Supérieure in Paris). To enter these schools, the very best students must go to a preparatory school for two years of intense study after high school, and compete in a national admission competition.

I went to the University of Lyon instead. And at the University of Lyon I was saved again by the high level of the lectures. I would even say too high, because it was too difficult for most of the students, but it saved me, because I could learn things in the proper way. In particular, I took a course in measure theory. I fell in love with measure theory, that was my first mathematical love, and it greatly influenced me during the rest of my life.

[BID/CFS]: *Where did you think your studies would lead you? We know you prepared for the Agrégation, the national competition by which higher secondary school teachers are selected in France. Did you have an idea where you wanted to go?*

MT: I had no idea what to do. Of course, I had to make a living, and I knew I had to make a living with the government. Because in case I became blind, they will find some spot for me. So the obvious way was to get the Agrégation, for which I prepared. I spent a lot of energy on that. I'm a dutiful person: when I start doing something I do it right. So I trained myself solving problems.

[BID/CFS]: *You did exceptionally well!*

MT: I did okay. Okay, I am still proud that my grade was 318 out of 320. That is an artificial grade, of course. It's just by comparison with others.

[BID/CFS]: *Then you got a position at CNRS. Perhaps you should first explain what CNRS is?*

MT: CNRS (Centre national de la recherche scientifique) is a research institute. When you get hired for CNRS, you have a position as a researcher for many years, and most of the time for your entire life. Essentially, you have no other duties than doing research. I'm very grateful for the French government to have given me one of these positions. There were no administrative duties, no teaching duties, you could devote yourself entirely to research. There was no control whatsoever, you study whatever you want. It's absolutely total freedom. And I benefitted immensely from that.

[BID/CFS]: *What role did Jean-Pierre Kahane play in you getting a position at CNRS?*

MT: Let me explain that to you. There are a number of positions every year, and my great luck was that in the year I applied, in 1974, this number was exceptionally large. If I had applied two years later, I would not have got the position. Since there were exceptionally many positions, they were also considering people who had not done any research yet, which was my case. The only thing I had in my favour was that my professors at the university were aware of the fact that they didn't very often get students like me. Four of them wrote a recommendation letter for me which reached the hiring committee.

One of the members of the hiring committee was J.-P. Kahane, a famous French mathematician. J.-P. Kahane was a very dutiful person. He wrote to me personally and asked me to please explain my situation: Why was I in the university and not in the grandes écoles system? Otherwise I wouldn't have a chance. So I described my health problem and why I went to the university. That I loved mathematics and wanted to do it. And I got hired!

Michel Talagrand receives the 2024 Abel Prize from His Royal Highness Crown Prince Haakon at the university aula, 21 May.
(© Alf Simensen – NTB / The Abel Prize)

I thanked J.-P. Kahane many years later, and he gave me this beautiful answer: "I just read your letter to the hiring committee, I didn't do anything." That's what he said, and I greatly admire him for doing that.

A problem-solving machine

[BID/CFS]: *Then, after you got your CNRS position, you started on your Ph.D. study?*

MT: Yes, I did. My instinct told me that I shouldn't stay in Lyon, it was no longer the right place for me. So I inquired where I should go, and I was "sent" to the group of professor Gustave Choquet in Paris, a very active group at that time. It ended up being a good place to be for me. Of course, it was very difficult in the beginning. I arrived there, I didn't know any relevant mathematics, and I was not able to make any choice by myself. I tried to follow the seminars, in which I didn't understand a word for a long time. Of course, as you begin you cannot read papers, because these refer to other papers that you don't understand either. It's difficult to get started.

I went to see professor Choquet and I said: "Please, I need to survive, pose me some problems that I can focus on." He gave me some problems, and one of them I could solve pretty easily. Choquet himself had tried for a few days to solve this problem. So he gave me credit for solving it. After that I didn't have to line up for one hour to talk to him in his office. That was a great privilege! And I got my Ph.D. in 1977, after three years of study.

[BID/CFS]: *We liked the comment that your Ph.D. advisor Gustave Choquet made to your father at the defence of your thesis. He said that you were "a problem-solving machine."*

MT: That's what he told my father, yes.

[BID/CFS]: *On this topic, you yourself have said that it* is *fun to solve problems.*

MT: But you see, this raises an important point. How do you choose the problem on which you work? First, it has to be in the right area, and then it has to be at the right level of difficulty. That's the most delicate part. If it's too easy, it's an exercise, it doesn't bring anything. If it's too hard, you get discouraged, and you don't have a chance. In my case, I was not in a position to choose a problem by myself, because I didn't have any overview of mathematics.

So I asked other people what problems they had, and that was often successful. Some problems were sound. I remember one from that time: Take a Banach space and give it the weak topology and the norm topology, respectively. Do they have the same Borel sets? Okay, it's reasonable to ask this question. Now, of course, as you expect, if you take a really large Banach space the answer will be no, but it requires some effort to prove that.

Okay, then you have a paper, but it doesn't go anywhere. Many papers I wrote were like that, they didn't go anywhere. But the thing is, I explored many areas, and then finally I hit some directions which were much more fruitful. I became interested in probability theory. It was measure theory that brought me to probability theory.

The first effort I did in probability theory was really thinking about vector-valued functions and what are the right notions of that? This brought me to the Glivenko–Cantelli problem, characterizing when the law of large numbers is uniformly valid on a family of functions. That again brought me to more central questions of probability theory. Furthermore, it was very important for me that Gilles Pisier joined our group in 1983. I will come back to that later.

[BID/CFS]: *What you're telling us indicates strongly that you are more of a problem solver than a theory builder.*

MT: I am not a theory builder. I don't have an overview of things, so I attack concrete problems, and if it works I try to push them. But I would say that the main feature of my work style is that I try to get a full understanding. I cannot stop until I feel I completely understand the problem. And that has turned out to be a fruitful way for me.

[BID/CFS]: *Choquet gave you advice on how you should attack a problem. Could you comment on that?*

MT: Okay, one of the first things I asked professor Choquet was to please advise me on how to do research. And he gave me the most useful advice I ever got, which I called the Choquet principle, which was well known before him, but I received it from him.

When you attack a problem, always choose the proper setting for the problem. And the proper setting is that it should have no extra structure, it should be the minimal structure where the problem makes sense.

The obvious reason for that is that you don't get distracted by things which are not relevant for the problem. I have applied that advice several times, with great success I would say.

[BID/CFS]: *You go even further than that. We have the impression that when you attack a problem, you exhaust the problem, you really tear it apart.*

MT: I cannot understand things halfway. I try to understand things in depth, but that's a very slow process. For instance, I tried to read Feller's book on probability theory. I read the book, and I put it on the shelf. And one month later, I didn't remember a word because I didn't go deep enough into it; I didn't chew it long enough. Having to chew things over and over again is a time-consuming process, of course, so often I have to ask people who have an overview about things.

[BID/CFS]: *On the other hand, when you gather all this experience from doing all these calculations, you must yourself gain some overview of the subject at hand?*

MT: To get familiar with an object you have to play with it. Now, when the object is too complicated, you play with a simplified version, which you believe has some of the characteristics of what really interests you. If you are lucky, or if you look in the right direction, you end up making some simple computation which actually reflects some part of the general phenomenon. And if you can do that it orients you, of course. I spent a lot of time doing that, trying to look for a direction and understanding the basic mechanism.

The most important event

[BID/CFS]: *In 1978, you went to Vancouver.*

MT: I had done some work on a topic called invariant means. It was sort of a failed attempt, because it didn't go very far. But I got invited to spend the fall of 1978 at the University of British Columbia in Vancouver, and I had a great time there. Coming back from Vancouver, I decided to make a stopover at places where I knew people. One such place was Kent, Ohio, where I had the most important event of my life.

[BID/CFS]: *Tell us!*

Talagrand at the reception following the ceremony.
(© Fotograf Thomas Eckhoff AS)

MT: I met my future wife, Wansoo Rhee, and that was an extraordinary piece of luck. She has supported my mathematical work in a way which cannot be overestimated.

[BID/CFS]: *Wansoo Rhee was a student at the time, right?*

MT: She was a Ph.D. student. There were several people on the doctoral committee, including Joseph Diestel, who was a very respected person in Banach space theory, and who was the person who had invited me. I was in the office of Diestel discussing mathematics when she came in bringing a copy of her thesis. And I looked at her, and basically that was it! She was a student in probability theory, which I didn't know anything about at the time.

Apparently, Diestel said good words about me to Wansoo. She got somewhat interested, also because her father, who was a very prominent scholar in South Korea, had taught his children that the only real value in life is scholarly knowledge. For a mathematician to find a wife who has been told that as a child, this is an absolute miracle. She always totally respected my work, and I wouldn't be here without her constant support.

[BID/CFS]: *When did you get married?*

MT: After some years of wooing, Wansoo agreed to become my wife in 1981.

[BID/CFS]: *That same year you had your closest brush with blindness. Could you tell us about this dramatic event?*

MT: I lived in terror, and terror is the right word, to become blind. At some point I felt that it was too much, and I should free myself from that. And I did something, which in retrospect is absolutely stupid. I stopped seeing an ophthalmologist because no symptoms had appeared for a time. In 1981, I took a trip to India. You see, I could function even though I was a little bit handicapped visually; I could travel by myself. At a train station in India, somebody took a razor blade and cut off the bottom of my bag I was carrying and got all my camera lenses, as well as my sunglasses.

I cannot function without sunglasses, so, on my return to France I went to see my ophthalmologist and asked her to please give me a prescription for sunglasses. She looked at my right eye and said: "Wait, what is your problem?" When I explained it she said: "You are crazy, you must check up your retina." So I made an appointment to check up my retina, and my retina was on the verge of detaching.

If I had not seen her, I would have become blind within a few months. And that would have been it. I was really saved by these very specific circumstances. This ophthalmologist was really a great person, because she gave me emergency laser surgery the same day the whole hospital was on strike. She had to save me, she said, strike or no strike, this goes first. You see, there are people like that. And I'm very grateful that I met someone like that.

Just after that, I finally got a phone call telling me that Wansoo would marry me. So that was fantastic!

[BID/CFS]: *She was then in Ohio?*

MT: She was at that time in Ohio, and she called me from Ohio.

[BID/CFS]: *And you were married the same year?*

MT: Yes, we were married as fast as we could!

Road to probability

[BID/CFS]: *Getting back to mathematics, could you tell us in more detail how measure theory, which you described as you first love in mathematics, led you to probability theory. How would you describe this transition?*

MT: Okay, there was this intermediate step, which was the Glivenko–Cantelli problem mentioned above, characterizing the classes of functions on which the law of large numbers holds uniformly. This is half measure theory, because you don't really have any complicated concept of probability, just the law of large numbers. You know, it's so simple. And then it's largely part of measure theory, because you have to work with the combinatorics of the classes of functions. There is no Brownian motion, no stochastic integral, this is very basic.

Then what happened was that I became aware of this field called probability in Banach space, which had already been developed for some time. What people were trying to do in probability in Banach space was that, instead of looking at probability in two- or three-dimensional space, they looked at probability in higher-dimensional spaces. One was trying to copy what had been done in small dimensions. And it came exactly at the right time, because that's the time when high dimensionality starts to be important in mathematics, and it had not been explored before.

So there was this entire field – I didn't want to say it was waiting for me – but it had not been explored enough in depth. I arrived just at the right moment where this was gaining importance, and there were still many things to discover. The transition was through probability in Banach space, and then Gilles Pisier asked me about the suprema of Gaussian processes, which was a rather well-known problem in that area. And it was easy, having gone through probability in Banach space, to connect to that field.

You know, the world of mathematics has changed. Probability was not considered as mathematics when I was a student. In Lyon there was no graduate course in probability. In fact, I didn't take any course in probability ever, which somehow is very positive, because I was not formed by the standard way of thinking about these things. I could have a different approach.

Boundedness of Gaussian processes

[BID/CFS]: *Your solution in 1985 to the problem of characterizing boundedness of Gaussian processes was arguably your first "big" result in probability theory. This was your starting point for studying boundedness of stochastic processes in more generality, including the so-called Bernoulli processes.*

You mentioned in one of your books the practical relevance of some of this, namely if your cellar is in danger of being filled with water, what is the likelihood of that happening?

MT: All around us now we have models. We use everywhere models of stochastic processes. Now, the illustration I gave is because I had a beautiful house just beside a river. When I bought the house I didn't know that the river sometimes swells and gets into the house. I do wish it had been only the cellar, but several times we got four feet of water in the first level of the house, where our offices were located.

The level of the river is modelled as a stochastic process, because it depends on so many elements. The best way to understand it is to think of it as random. You want to know the maximum of the process, which in this concrete case means whether the river will visit you or not.

This is a very important criterion, and it applies in so many situations; for example, if you study the stock market. As for boundedness of Gaussian processes, I gave a complete understanding of that in some sense. There are two ingredients, one of probabilistic nature, and the other one of geometric nature. Indeed, the index set is naturally a metric space, and you have to deal with its geometry.

Here I should make an interesting comment: this metric space is not *any* metric space, it is a very special metric space, because it's a subset of a Hilbert space. But if you try to use the fact that it's a subset of a Hilbert space, you are dead! The successful construction is to forget that completely and think of it as an abstract metric space. Make general arguments true in any metric space. That's the key to success: forget about what is irrelevant. Of course, if it doesn't work, you can always come back to the specific features of your problem. But first forget about it. In my case this approach was greatly successful.

[BID/CFS]: *Which role did Xavier Fernique play in your solution to the problem of characterizing boundedness of Gaussian processes?*

MT: Mathematicians often mimic what has been done before. There was a standard method to bound stochastic processes, but that method will not give the right result for Gaussian processes. The person who really made the breakthrough was Fernique. He found a better way to bound Gaussian processes. It was very messy and very difficult to understand, but that doesn't matter. What matters is that he made the breakthrough.

Fernique's bound had the chance to be the correct one, while the other bounds had no chance – there were very simple counterexamples. I proved that Fernique's bound was actually of the correct order, it could be reversed, modulo the universal constant which gives you the right order of the maximum of the Gaussian process. The key step was a construction in an abstract metric space, which, after you succeed in doing it, makes you really wonder why you didn't do it before.

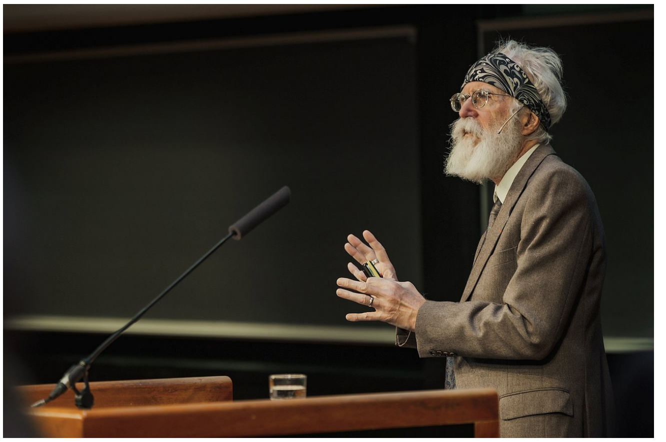
[BID/CFS]: *At the time you proved the bound on Gaussian processes, you considered this your best result, right?*

MT: It was the best known problem that I had solved up to that time. People in probability were well aware of that problem, which you could argue goes back to Kolmogorov.

[BID/CFS]: *Could you explain the concept "chaining," in particular, "generic chaining," and its significance?*

MT: The way I initially saw this was through Fernique's concept of majorizing measure. It took me a very long time to understand that these complicated things that Fernique was doing, could in fact be done in a very simple way with a slight change of perspective.

You see, this is the beauty of mathematics. You have something very complicated, and you make a slight change of perspective, and it becomes very simple. The slight change of perspective took me 15 years! And after you found it, you say: *Boy, why didn't I do that in 10 minutes?*, which is the time it takes to learn the stuff. But



Talagrand lectures at the Abel Symposium.
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that's not the way it works. In fact, preconception, which prevents us from looking in new directions, is the worst enemy of a research mathematician.

Generic chaining is really a method to bound a stochastic process. Kolmogorov was doing that by having successive approximations, which were getting more and more complex, and studying what happens when you go from one approximation to the next one; really keeping very closely track of what happens. The generic chaining does exactly the same, but the successive approximations are defined in a more flexible way.

When I solved the problem for Gaussian processes, of course, I was young and full of hope. So I say, this result about Gaussian processes tells you really – if you think about it philosophically – that the universe is as simple as it can be concerning Gaussian processes, in the sense that you can have a complete understanding of the thing just by looking at the structure of a certain metric space. It's an absolute miracle!

And I thought, why wouldn't there be more miracles like that? So I made a series of conjectures about all kinds of processes, which would essentially say that if you do the chaining the most clever way, you will really extract all essentials of the problem. I made these conjectures before 1990, and incredibly, they are all solved now in a positive way. So, concerning stochastic processes, from my point of view the universe is as nice and as simple as it could be. This is fabulous. And of course, I was lucky that it was that way. Otherwise, I would have worked for nothing.

Concentration of measure

[BID/CFS]: *Let us move to what is called the concentration of measure phenomenon. You yourself have said that your discovery of the first concentration inequality was a magical experience. Let's start* *with the classical two-dimensional isoperimetric inequality, which states that if we have a closed string of length L, then $L^2 \geq 4\pi A$, where A is the area that the string encloses in the plane. We have equality if and only if we have a circle. How is this isoperimetric problem related to concentration of measure?*

MT: Okay, I will try to explain that. The example you mentioned was of course known to the ancient Greeks. So it took some time. This one takes place in the plane, while the work I'm doing is in high dimensions.

So, I have to move to, let's say, the Euclidean space of n dimensions. Let me state a simple problem very much related. You take a body of a given volume in an n-dimensional space, and you look at the set of points in the whole space which are within distance t of that body. How small can the volume of that set be? There is an extreme situation which occurs when your original body is a ball. Then you can compute everything, since the set within the given distance is another ball. That's the extremal case. But in that setting, you don't yet see concentration of measure. To see concentration of measure, you have to move to the sphere. So you take the sphere of radius $\sqrt{n}$ (the proper normalization) in the n-dimensional Euclidean space. It's something we don't really visualize.

This phenomenon is precisely described by the famous Lévy's isoperimetric inequality, which he proved in 1917. It is remarkable how long it took for the consequences of this discovery to develop. The breakthrough was made by a probabilist, but it took well over 50 years to really influence probability.

Let me give a simple example: on the sphere you take a set of measure one half. It contains half of the points of the sphere. Now you look at the set X of points on the sphere within distance t of that set. What happens is that the set X is almost all the sphere. In fact, the points that are not within distance t, that is, the complement of X, their measure is at most $e^{-t^2/2}$. So it decreases exponentially fast, and it's independent of the dimension of the sphere. That's what is important here.

A consequence is that if you have a well-behaved function on the sphere, say a Lipschitz function, then it has a great tendency to be nearly constant. Now nearly constant means that its fluctuation will be the same however large the sphere is. That's actually a very deep generalization of the law of large numbers. I learned that idea from Vitaly Milman, and Milman and Michael Gromov worked on that. They developed the phenomenon of concentration of measure, which is sort of a generalization of what happens for the sphere.

[BID/CFS]: *Did Paul Lévy see that?*

MT: No, Lévy didn't see that. He died in '71. Now the sphere, that is geometry, and geometry isn't my field. My field is product spaces. Products of different measure spaces, that's what I was thinking about. It was known that you have some phenomenon of concentration of measure in a product space. In fact, if you take a subset A of the product which contains at least half of the points, essentially every point x in the product is close to A in the sense that one can find a point y in A which differs from x on at most about $\sqrt{n}$ coordinates. In fact, on specific examples one sees that much more is true. Namely, denoting by $I(y)$ the set of coordinates where x and y differ, y may vary over A such that the sets $I(y)$, while remaining of cardinality about $\sqrt{n}$, are widely different. The convexified inequality which I discuss below captures this phenomenon and quantifies it.

However, I was motivated by some rather special problems of probability in Banach space. I wondered whether you could have some other notions of closeness which would exhibit the same phenomenon. My great luck was that there were and that nobody had looked at them with the proper point of view. With the proper point of view it was actually not that difficult to discover this. So, you have this general statement that if in the product space you take a set large enough that it contains half of the points, then in various senses of closeness, most of the points are close to that set.

This has great many applications to probability, because there are so many probabilistic objects that are built on independent random variables. The remarkable thing about that is that you could argue that this comes from isoperimetric ideas, but the isoperimetry has disappeared! There is nothing like a boundary of a set, and what remains is only the concentration of measure phenomenon. I stress again that the important consequence is the concentration of measure.

I express my gratitude to Vitaly Milman, because he's the one who convinced me that that was the important idea. I must admit that the first or the second time I saw him talking of that, I thought: this guy is obsessed. What is the point of all that? No, he was a person who had a vision! Now, having the vision and being able to prove technically the thing, there is some distance. But you cannot do without a vision, and he was the one who brought that to me.

[BID/CFS]: *Out of this came what is called the Talagrand convexified inequality, right?*

MT: In the convexified inequality, to measure the "distance" of a point x of a product of n spaces to a subset A of this product, you take a suitable convex hull. More precisely, to each point y of A you associate a sequence of length n were the ith term is zero if the corresponding coordinates of y and x coincide, and is 1 otherwise. Then the distance of x to A is the Euclidean distance from the origin to the convex hull of this set of sequences as y varies in A. The main conclusion of the inequality is that if A contains at least half of the points, the size of the set of points at distance $\geq t$ from A is very small (like a Gaussian tail) independently of n.

There is a kind of miracle that happens. It is really a kind of abstract version of the law of large numbers which has a great many consequences. For instance, when you study combinatorial optimization you will take some random data and try to make a construction. For example, you take n random points in the unit square, and you look at the shortest path through them. Now this is a random variable. What is the fluctuation of this random variable? It turns out that the convexified inequality gives you bounds that are of the correct order.

[BID/CFS]: *And the hint about taking convex hulls came from Choquet?*

MT: Yes. Now this is unbelievable! When I asked Choquet for his advice, he explained to me the Choquet principle, which we talked about earlier. Then he said: "It's often useful to take a convex hull," which is what I did. And then he said: "It also helps very much to consider products." Now I spent my life working with product measures. I don't know if you believe in coincidences, but the funny thing is that the three advices I got from Choquet turned out to be relevant in my most successful research.

[BID/CFS]: *You have to tell us the taxi driver story!*

MT: I used to have a small taxi company to take me from my place to the airport. One Sunday I went to the airport with them. And when I gave my credit card to the taxi driver, he looked at my name and asked: "Oh, are you the mathematician?" The explanation for that was that he was the boss of the company, and he had learned about this inequality in business school. So it was considered simple enough so that it could be presented at a high level probability course in business school. Okay, being recognized by a taxi driver, that's something to be cherished!

[BID/CFS]: *Do you consider this to be your best result?*

MT: It's surely the most popular, and the one most people will learn. It's probably the one which will be referred to the longest. A host of examples shows that it captures at a deep level something which seems nearly optimal in many circumstances. So I'm glad I proved this result.

[BID/CFS]: *Terence Tao commented on the Talagrand convexified inequality, saying the following: "Talagrand's inequality implies that convex Lipschitz functions of Bernoulli variables concentrate as if they were Gaussian." Does that summarize what the Talagrand inequality says?*

MT: The inequality is fairly more general than that, but this is one of the most striking consequences. Terence Tao must have liked this inequality, since he reproduced the proof on his blog.

Talagrand lays down the wreath at the Abel monument, Oslo.
(© Eirik Furu Baardsen / DNVA)

Spin glasses

[BID/CFS]: *Let's move on to another big result that you proved, this time with connections to physics. How and when did you become acquainted with the spin glass phenomenon in physics and, in particular, the so-called Parisi formula?*

MT: At a conference I met Erwin Bolthausen, who is a well-respected probabilist, and who was interested in applied things. He wrote the Hamiltonian of the Sherrington–Kirkpatrick model on a blackboard. The Sherrington–Kirkpatrick model is a model for disordered matter. The interaction between any two given atoms is given by a Gaussian random variable. So, you have a bunch of independent Gaussian random variables, and I foolishly thought that I understood this better than anybody else, so that I would be able to make progress on that model. By the time I understood that this was an absolutely stupid illusion, I was already hooked by the problem.

This program was a big challenge in the sense that one deals with a perfectly well defined mathematical object. And the physicists were studying it by methods which, okay, I won't qualify it, but you consider n copies of the system, and you compute a quantity depending on n, and then you take n to be a negative number. Then you draw some conclusion from that formula.

[BID/CFS]: *That's what you call witchcraft, right?*

MT: That's what I call witchcraft. But this is not a coincidence! This cannot be a coincidence, there must be some deeper reason. It's like Euler's formula $1 + 2 + 3 + \cdots = -1/12$, which occurs in connection with Riemann's zeta function. It's this kind of formula, there must be something which remains to be understood in the future. But there was this challenge to have this mathematical theory being studied by methods from physics. How can you do it by purely mathematical means?

The challenge was well known, and I got this problem at a period of my life where I was stuck on stochastic processes. I was stuck on everything I wanted to do. So, I said to myself: "Why not, there is nothing to lose by trying."

[BID/CFS]: *And this was in 1995?*

MT: This is about 1995, when I got stuck because I couldn't solve what I called the Bernoulli conjecture, which incidentally was solved by Witold Bednorz and Rafał Latała in 2011. And so I proceeded in a very humble way …

[BID/CFS]: *As you always do!*

MT: I always say, you have to start from the beginning. If you don't understand the simple things, you won't solve the difficult ones. It sounds so obvious. So I ask myself, what's the minimum challenge? Prove anything at all on any model at all. That's low enough. Then I explored a number of models, starting from the bottom, and there was basically no mathematics which had been done on that. I worked really hard for a very long time and without much hope of success, you know.

After about eight years of very hard work I was lucky. You could summarize it in a three-line observation, which looked completely trivial. You had to find the lower bound for a certain quantity. The observation was that you take two similar quantities that you couple in a certain way, and if you can find an upper bound for that it will give you the lower bound you look for. That completely changed the problem, because there are methods to find upper bounds that Francisco Guerra had developed, and these methods could be applied with a small variation.

Thus, I was able to prove Parisi's formula for the free energy. You had to make this crucial little observation, which I made by exploring and exploring, without much hope, in fact.

[BID/CFS]: *Is it correct to say that you didn't invent new mathematics to prove the Parisi formula?*

MT: No, I didn't. The mathematicians couldn't solve that, and the reason they couldn't – and many good people tried – was because they were not humble enough. They thought they were going to solve that in two weeks. No, that's not the case. They should have started from the beginning.

The physicists thought that new mathematics was needed. Now, I understand why, because it's about quantum field theory. Quantum field theory is something that the mathematician has not been able to fix, and it's clear that new mathematics are needed for that. The physicists thought – not unreasonably – that "new mathematics" would also be needed to prove the Parisi formula, but no, "old mathematics" worked very well for that, and I'm very happy I did that.

But I wouldn't say this is an important result. It is nice to have removed that "thorn" in the flesh of mathematicians, you know, that they couldn't duplicate the physicists' work. But mean-field models like the Sherrington–Kirkpatrick model are not really important. What would be important is to understand real models for spin glasses, like the Edwards–Anderson model, and these nobody knows how to handle, including the physicists, who even don't agree on what the solution is.

[BID/CFS]: *Proving the Parisi formula was an important ingredient in you being awarded the Shaw Prize in 2019, and Giorgio Parisi was awarded the Nobel Prize in physics in 2021.*

MT: Parisi is such a nice person. He gave a lecture at Institut Henri Poincaré, very soon after my solution, and he said: "Now we are sure that the solution is correct." Of course, every physicist was absolutely convinced that Parisi had found the right solution, but he was gentleman enough to acknowledge my contribution, which was so nice to hear.

Revisiting old problems

[BID/CFS]: *And then in 2005, you had had enough, so to say, of the Sherrington–Kirkpatrick model, and you wanted to do something else. You went back to the control measure problem. Tell us about that.*

MT: There is actually a fruitful stage in your life when you have nothing to lose, and only to gain, because you can make bets, like the bet I made for spin glasses in physics, which miraculously worked out. So I say, okay, why don't I go back to one of the problems of my youth, which was called the control measure problem, and which I couldn't solve? You can argue that the problem goes back to von Neumann, or at least to Dorothy Maharam, who introduced the concept called Maharam algebra. This problem was 58 years old, and many people had attacked it, without success, including me in my youth.

By 2005, two major new ideas had been invented (by Jim Roberts and Ilijas Farah) relative to this problem's core question. It took me only a few weeks to combine the two to produce a beautiful counterexample to the control measure problem. Technically, what I did was to construct a Maharam algebra that is not a measure algebra. This means that there exist measure algebras which are complicated and do things which you wouldn't expect. And maybe one day they will be used for something.

[BID/CFS]: *But you also revisited random Fourier series?*

Talagrand signs the protocol at the Norwegian Academy of Science and Letters. (© Eirik Furu Baardsen /DNVA)

MT: Fourier series are my obsession! I started being interested in random Fourier series when I wrote the book with Michel Ledoux, titled: "Probability in Banach spaces." Random Fourier series certainly belong to that area. Great advances were made by Michael Marcus and Gilles Pisier. I read their paper, and found an alternate proof, which, from my point of view, is somewhat simpler.

However, I felt I didn't fully understand the topic, and so I kept thinking about it, even though nobody was interested. But it was a good idea to do so, because when you try to study general stochastic processes, there are different difficulties which merge together at the same time. There are difficulties coming from the fact that your random variables are complicated, and there are difficulties coming from the fact that somehow your index space is not homogeneous, so that the same thing does not happen everywhere. You have to take this into account.

For random Fourier series one of the difficulties disappears, because there is some homogeneity over the whole space. So you get half of the difficulty away and can concentrate on the other half.

This was important, because several of the ideas which turned out to be very fruitful later on in studying general stochastic processes I discovered by studying random Fourier series. So it was a great instrument of discovery.

Marcus and Pisier had some conditions which I tried to remove. I tried to understand this in full generality, and the nice reward I got at the very end was that I dared make the right conjecture. This conjecture essentially says that the partial sums converge uniformly almost surely exactly when the random Fourier series is a mixture of two different specific types, for which the convergence is pretty obvious. So nature is as simple as it can be. It looks complicated, but that's because you don't know how to look. If you know how to look, there is a mixture of two very simple cases, which, notably, converge for entirely different reasons.

[BID/CFS]: *That must have been a very exciting discovery?*

MT: It was. I was almost 70 at the time, and I had had a brain haemorrhage six months earlier!

On old mathematicians and on writing books

[BID/CFS]: *And now we're at the stage where you actually are revisiting many of your earlier ideas, and actually are improving on them. You rewrote one of your books, for example.*

MT: It is difficult, you know: how do you have a constructive end of your career when you are a mathematician? My own belief is that it is very dangerous to keep working on the same topics, because the odds are against that you will make great progress. So, I applied that philosophy in which I believed, and stopped doing research when I was around 58 years of age.

I tried to have fun, and to have fun was learning physics, which I didn't learn at college. I ran into quantum field theory – the rest was easy. Well, you cannot say that general relativity is easy, but it is a purely mathematical theory. So, if you're a mathematician and work at it, you will understand it very well. Now, quantum field theory is not mathematical, and there is no place where it can be learned easily. The work done by physicists is a different world, different way of thinking, different language and not the same idea of what an argument is.

I worked as much on that topic as I did on spin glasses. Of course, I didn't contribute anything, but I explained a little bit of the theory to myself and hopefully to other people. I spent ten years doing that, and actually, I'm revising this book now, which will almost certainly be my last piece of work. The title of the book is "What is a Quantum Field Theory?", with subtitle "A First Introduction for Mathematicians." I never worked as hard to explain things like I did in this book.

[BID/CFS]: *You have written six voluminous books, one of them with a co-author. That must have taken a tremendous amount of time?*

MT: I've seen a picture of Donald Knuth, sitting in front of the books he wrote. There is an entire bookshelf, you know. So what are six books? Just a few years of work, right? Actually, except for the book with Michel Ledoux and the last two, they are just huge papers in the sense that I collected the results and unified the notation, but did not work as hard as I should have on the quality of the exposition.

[BID/CFS]: *You offered a prize of $5000 for the solution of questions surrounding what you call Bernoulli processes. Could you tell us about that?*

MT: I certainly can. You see, after doing the characterization of Gaussian processes, you ask yourself, what's the next most important process which you should try to understand? What is the most basic random variable? It is the coin-flipping random variable. So the random variable takes value one or minus one with equal probability, it cannot be simpler than that. Now you take linear combinations of these, and you get a new random variable. Varying the linear combinations, you get a family of random variables, a stochastic process, and you have to understand the supremum of this process. So, based on purely philosophical grounds, you know this is the simplest possible situation, therefore it must be fundamental. That's really the thing. I saw that this is a fundamental problem, and I worked very hard on it.

However, I couldn't solve it, and to make it known that I considered it to be important, I offered $5000 for the solution. This is another happy story: it was solved by two Polish mathematicians, Rafał Latała and Witold Bednorz. Latała essentially started on this problem when he was a student. He thought about it for 20 years before he solved it. The $5000 prize money was well deserved for the solution of this problem. I was happy to pay them. They actually went hiking with that!

What is interesting is that the philosophical consideration that this was very simple, and therefore fundamental, was absolutely true. I mentioned earlier that all the conjectures from around 1990 were solved. The key ingredient is, as I had guessed, the understanding of Bernoulli processes. When I stressed the importance of this result, I did not know how it would be used, and it did take some time to figure this out. But philosophy turned out to be a faithful guide here.

[BID/CFS]: *The prize money of $5000 that you paid out, that was a spin-off of your Shaw Prize money, right?*

MT: Oh, no, no, that was my own money! This was in 2011, while I was awarded the Shaw Prize in 2019. I didn't tell my wife that I was offering this money. I didn't want to be upbraided!

[BID/CFS]: *We wouldn't tell our wives, either!*

MT: With the Shaw Prize money, and now also with the Abel Prize money, I will establish a significant mathematical prize, starting in 2032, or before if I die. It's a mathematical prize not only in the areas where I work, but in areas where I understand enough to have a great respect for the work which is being done. These include functional analysis, probability theory, theoretical foundations of computer science and combinatorics. I have a special taste for combinatorics because many of my work have some combinatorial component in them.

[BID/CFS]: *G. F. Hardy, in his book "A Mathematician's Apology," said the following: "Mathematics is a young man's game." He also said: "A mathematician may still be competent enough at 60, but it is useless to expect him to have original ideas." Now we compare that with what you wrote in your autobiography: "Preconception, which prevents us from looking in new directions, is the worst enemy of a research mathematician. This is also one reason why big advances are often made by younger researchers; the older ones know too much." Comment please!*

MT: I had Hardy's book on my desk in the office I was sharing as a student. So I read his book when I was younger, and I was greatly influenced by what he said. I was also greatly influenced by professor Choquet, who one day asked me: "Talagrand, how old are you?" I answered: "Sir, I'm 29" and he said: "You have to hurry up, you have exactly one year to prove something important." That really was traumatic, even though he said it half jokingly.

On the other hand, I witnessed the most magic experience of a mathematician: you get this idea in your mind, and you feel that it wasn't there before. It's something which is a new step, and it's marvellous enough that I could identify that clearly happening to me. During the magic mathematical period of my life from 1985 to 1995, it occurred approximately every six months. And then it became more and more rare. And then it completely stopped. At least the feeling I had completely stopped. It didn't mean that I didn't have some small ideas. But I got the message that it's time to stop. I'm not going anywhere. That's the way I felt.

On the other hand, this discovery I mentioned about the convergence of random Fourier series, which I did when I was almost 70 years old, seems to contradict that. So it's complicated.

[BID/CFS]: *Do you have any special interest besides mathematics?*

MT: Oh, I am very mediocre at anything else than mathematics. I've entirely focused my life on mathematics.

[BID/CFS]: *But you did run a marathon once?*

MT: Okay, that was to compensate from having been excluded to do any sport because of my eyes. I had to explore my own natural energy and I discovered that if you're a normal person and spend six months training for a marathon, you can do it. It's a very interesting experience. I recommend it to everybody as part of life.

[BID/CFS]: *And you've travelled widely, haven't you?*

MT: That is a family interest. We have to do things together to work as a family. I am also a cultural animal. I spend my life in museums, and I greatly enjoyed one in Oslo.

[BID/CFS]: *Well, on behalf of the Norwegian Mathematical Society, the European Mathematical Society and both of us, we would thank you for this most interesting interview.*

Christian Skau, Bjørn Ian Dundas, Michel Talagrand.
(Photograph by Erlend Gjertsen, Gyro A/S)

MT: I would like to thank the Norwegian people for celebrating mathematics the way they do. The way they put mathematics forward is praiseworthy, and mathematicians are greatly honoured and thankful for that.

[BID/CFS]: *Nice to hear. Thank you!*

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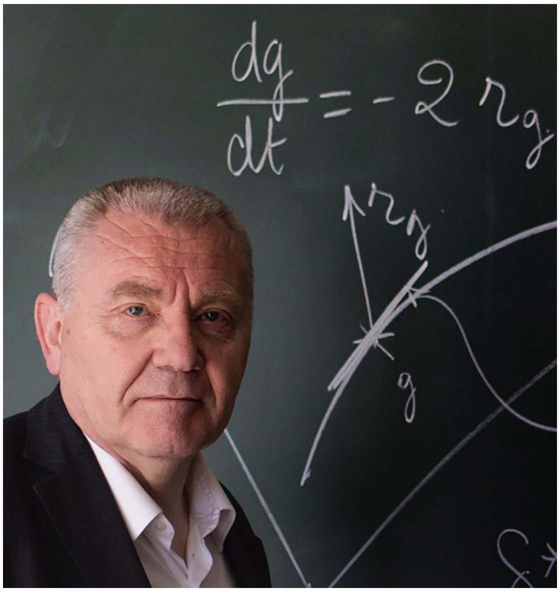
Interview with Jean-Pierre Bourguignon

A slightly edited version of an interview that was conducted by videoconference on 24 January 2024

Martin Raussen



Jean-Pierre Bourguignon. (Photo: Jean-François Dars)

Martin Raussen: *Dear Professor Bourguignon, this interview will focus on your relations to European mathematics. You were the 2nd president of the European Mathematical Society in the period 1995–1998, succeeding Professor Friedrich Hirzebruch. But let us start with yourself and your career as a mathematician.*

School and mentors

MR: *You were born two years after the end of WW2 in Lyon in France. When did your particular interest in mathematical topics and questions arise? Did that already happen in school? Do you have any special recollections from that time?*

Jean-Pierre Bourguignon: Thank you for the opportunity to talk about my personal life. As you said, I was born two years after the war. My father had been a prisoner of war in Germany for five years, and that was of course a very important moment in his life.

He came from a poor peasant family where everybody had to work, and he couldn't even finish primary school normally, although he managed to get what is called in France the *Certificat d'études primaires*. My mother had better conditions and could go to school all the way. For both of them, it was very important to give their children the possibility to study.

My father had been very frustrated not to be able to learn more. Actually, after having been a prisoner of war he wanted his children to speak German because he felt that sharing a language is the first point of contact between people. From his time as a prisoner, he did not come back anti-German, but strongly anti-Nazi. So, I do speak German, because my father wanted that; German has been the first language I studied at school.

For my education, and that of my classmates, it has been very important that we attended the same school, Lycée Ampère Saxe in Lyon, for many years: from primary school to secondary school, what we now call *"le collège"* in France, and then the first two years of grammar school (*lycée*). I must say that I found school extremely enjoyable, because of the exceptional quality of the teachers. In primary schools in France, one teacher takes care of all subjects. As soon as you get to *collège*, you have specific teachers for specific subjects. I had the same mathematics teacher in *collège* for three years out of four and again the first two years of *lycée*. He was not a great mathematician, although he was very competent, and strict. He used the pupils who had no problem with mathematics to help the other ones. Having to explain mathematics to others is a very good way to deepen your understanding, almost without noticing it.

At the time, I was not especially interested in mathematics. I was doing well in almost every subject, in Latin, in French; I got very good grades in all fields. Actually, in the *lycée* I was much more interested in literature or philosophy. I read quite difficult philosophical books already when I was 14 or 15, because I found this much more challenging than mathematics. I learned mathematics without effort and got good grades, but I was not passionate about it. The same with physics, by the way. I didn't really work much. I was certainly very attentive during class. I don't remember working for school after dinner. In my family, everybody would go to bed at 9 p.m., as my father got up every day at 4.30 a.m.

EMS MAGAZINE 133 (2024) — DOI 10.4171/MAG/209

to go to work at the post office, and we were living in a small apartment.

A big change arose in the last year of high school. I had to move from where I had studied for so long to the main building of Lycée Ampère in the centre of Lyon. The mathematics teacher I had there was not very good from the pedagogical point of view, but he was passionate about mathematics and astronomy. His course was difficult to understand. You had the feeling that he was really telling you something deep and interesting, even if you couldn't get it. This was not very good for getting a good grade at the *baccalauréat* (French high school diploma). It gave me the urge that I had to understand what he told us. Consequently, this teacher induced me to work by myself. I tried to find books where I could really get an idea of what was going on in his class.

At the same time, since I had very good grades before, the physics teacher wanted me to take part in the competition for high school kids in France. I was trained every Saturday afternoon by him. I passed then this *"concours général"* in mathematics and physics, and in physics I did quite well without being at the very top. Of course, my grades in mathematics suddenly dropped and did so dramatically. If I remember correctly, my first grade was 0.5 out of 20. Some other people would even get 0.25 and 0, and the best grade would perhaps be 8 out of 20. That was a big shock for me!

Still, the physics teacher gave me the feeling that I was able to do science efficiently. A strange balance between somebody who was very supportive, helping me to really learn more about physics and so on, and a totally different personality who managed to capture my attention and my interest in mathematics.

After that, I went to what we call *"classes préparatoires"* in the French system. At the *baccalauréat* my grades in mathematics had been good, although not fantastic. Many of the other pupils there had far better grades in the exam. To my surprise, however, I felt much more comfortable than most of them. The reason is that the jump in level in mathematics between the *lycée* and the *classes préparatoires* is quite significant. Many of the other students struggled a lot, but not me! I already knew how to work by myself, and, to my surprise, I ended up number one or two in mathematics and physics in that class in the first year. The second year was much more difficult because the teacher then was very peculiar. He was certainly a remarkable mathematician. Still, his way of teaching was very strange: he graded people according to what he expected from them, and this in a year when students must pass the entrance competition for the *"grandes écoles"* at the end for which you need to position yourself in comparison with other students. Since I had been successful in the first year, he expected a lot from me, and I ended up disappointing him. As a result, I got bad grades while my neighbour in class, who achieved far less, ended up with better grades than me; very disconcerting! This told me that perhaps I was not good enough to do mathematics.

Portrait of a young mathematician

MR: *How did that change at the university?*

JPB: I entered *École polytechnique* in 1966. At this time, quite a significant part of the teaching consisted in mathematics and physics courses. It came quite unexpectedly to me and many of my fellow students that several of the teachers, in physics for example, were not so competent, if not truly incompetent, as the mechanics teacher was. My analysis teacher was Gustave Choquet, a great mathematician who was also highly motivating and extraordinarily elegant. The poor teaching we were subject to in some disciplines was not acceptable to a group of students, who decided to organise some kind of task force to substitute for the teachers. I was one of the leaders of that group. We took all possible books in mechanics, in French, in German, in English, in Russian, everything we could find, and we tried to build our own view of mechanics. The group I mention consisted of perhaps 12, 15, or 20 people out of the 300 students of the promotion. This is the way I became introduced to research in the first place, not at a very high level, and also to teamwork. Just to replace bad teachers! It may sound crazy, but it had the consequence that many of my fellows from that year at *École polytechnique* decided to become researchers.

During my time at *École polytechnique*, I learned a lot of science seriously, for example quantum physics, some other parts of mathematics, and, beyond this very peculiar work in mechanics, we organised a seminar on general relativity ourselves. Still, when I finished École polytechnique and compared the amount of mathematics I had learned with that my friends at École Normale Supérieure had been exposed to, I told myself that I was not knowledgeable enough to do mathematics professionally. This is why I looked for people in mechanics in Paris to tell them I wanted to study mechanics further. This was after 1968, and I had already a very clear idea of what kind of research problem I wanted to consider, which was solving the Euler equations for fluids in the spirit of Vladimir Arnold. When I told the mechanics professors I met in Paris what I wanted to do, all of them told me: *"No, this is not the way it works. We will tell you what to do"*! And so I went away to the field that was the closest to mechanics, namely differential geometry. Choquet was still my advisor, but of course, that was not his field. Therefore, I moved quickly on and became a student of Marcel Berger.

MR: *But your first degree was in Engineering, is that right?*

JPB: It was a degree from École polytechnique, an Engineering school. There the courses were essentially about fundamental science. During my time there, I also took several courses at the university, leading to a master's in mathematics from the University of Paris, not yet divided into several universities as it is now.

A career in mathematics

MR: *I learned that you got your first position in the CNRS already at age 21.*

JPB: Yes, but that time was very special. The CNRS was expanding very significantly. In that year 1969 alone, the number of people hired in mathematics was 36, if I remember correctly. Most of the people hired were a bit older than me, still very young. I had published one paper on mechanics. It was not really a research paper; at least for a student, it was not so bad to have a paper published. I was given the position very early without having a PhD. Actually, at that time there was no PhD in France but a *"thèse de troisième cycle,"* which today one would rather call a "master thesis." The main diploma was the *"thèse d'État,"* of the level of a habilitation, which I passed much later, in 1974.

With Berger and me being a CNRS fellow, everything became easier: he never tried to tell me what to do, I could do what I wanted. He gave me a fantastic gift: he had just entered the CNRS himself leaving his university position, and, since I was his only student having a CNRS position, he spent every Tuesday telling me everything he knew about geometry, which was great! The next day would be devoted to attending his seminar. There were very active and interesting participants, among them, e.g. Yves Colin de Verdière and Lionel Bérard Bergery. Berger himself was very modest, actually much too modest. He always claimed that he never did anything major, which is of course absolutely not true. For me, another major gift from him was that he put me in direct contact with extraordinary mathematicians such as Eugenio Calabi, Shiing-Shen Chern, Isadore Singer, Michael Atiyah, Jim Simons, and so on. Thanks to the introduction by Berger, I was given special access to these very special people.

I. M. Singer, J. Simons and J-P. Bourguignon, New York, 2012. (Photo: Friends of IHES)

MR: *You got a network right away.*

JPB: At that time, in France at least, when you were not doing algebraic geometry or number theory, you were not really a mathematician; I was therefore not one. Moreover, most mathematicians were very ignorant of physics. I was one of the very few mathematicians at that time who had a decent understanding of quantum mechanics, for example. It went back to my substantial training at École polytechnique, where I enjoyed a good teacher in that part of physics, and I had studied the subject thoroughly. As a result, I was in a privileged situation when the opportunity arose, with gauge theory, to get closer to physics and to read papers in that field, to understand problems posed by physicists, and to talk to them.

New connections in the US

MR: *And to make connections.*

JPB: Yes. A big opportunity came in June 1972 when Jim Simons invited me to Stony Brook. He had visited Paris and listened to me at the Berger seminar. The next day, probably after having spoken to Berger, he sent me a fax offering me a position to be taken on the 1st of September. Not an easy decision, although I could be on leave from my CNRS position. Still, my family was involved, and my wife too had her job, as a nurse. We already had a little girl. My wife in the end agreed, and we decided to go, a jump into the unknown.

In Stony Brook, there was an incredible concentration of differential geometers, 14 of them alone at that time: besides Simons himself, Shing-Tung Yau, Jeff Cheeger, Detlef Gromoll, Wolfgang Meyer, John Millson, James Ax, John Thorpe, Leonard Charlap, and a few others. It was for sure one of the best places in the world to be for a young differential geometer!

On top of that, Chen-Ning Yang was in the physics department. In early 1973, an attempt was made to organise a seminar on gauge theory between mathematicians and physicists. It stopped after three meetings.

MR: *Why that?*

JPB: Well, the physicists had the feeling that mathematicians were too obsessed about the global point of view with topological consequences, and the mathematicians found the physicists too obsessed about the local gauge invariance. Anyway, I had exchanges there with very good theoretical physicists and, thanks to my initial training, I was one of the few mathematicians who could really talk to them without being lost. By the way, it was exactly at that time that Simons, together with Chern, developed the Chern–Simons theory.

Bourguignon and Calabi in the IHÉS auditorium, 2007.
(Photo: Jean-François Dars)

This visit to the US has been extremely important for me because of the fantastic concentration of differential geometers in Stony Brook. Moreover, it was there that I met Yau. We were both teaching calculus. This helped us become good friends. We worked together and we published a joint paper in which we tried to disprove the Calabi conjecture, which of course turned out to be a wrong attempt!

Then, I spent the summer 1973 at Stanford at the invitation of Robert Osserman. During this visit, I received a call from Chern inviting me to have lunch with him. I was rather amazed that he wanted to talk with me. I had met him briefly before, in Oberwolfach, in 1970 or 1971. He just wanted to know what I was doing. Later, I learned that he did that with several young people.

This meeting changed a bit my psychology because it gave me the feeling that what I was doing was perhaps not so stupid. After all, if Chern wants to hear about it, it may be worth the effort!

At the end of the summer, my wife and I decided to come back to France and not to stay in the US. Thanks to this stay, I got really close to Jim Simons, and, later, this made a huge difference for me in many ways.

The connection to gauge theory developed further. I think the best paper I published was written jointly with Blaine Lawson in the late 1970s. Blaine had been visiting IHÉS (Institut des Hautes Études Scientifiques in Bures-sur Yvette on the outskirts of Paris) for the academic year 1977/78. We talked to each other from time to time. At some point, I had to prepare a course to introduce physicists to the mathematics of gauge theories, and I submitted my draft to Blaine. Physicists had a conjecture about stable Yang–Mills fields on the 4-sphere. At some point, I mentioned to him that I knew how to do half of the proof, and Blaine said: *"Really? I know how to do the other half!"* And so, just talking to each other, within a week, we had the paper! Of course, we could have spoken to each other much earlier in that year, I was struggling with the part I couldn't do, and he was struggling with the part he couldn't do.

The inspiration for the result came from what has probably been the last published paper by Jim Simons, at a conference in Tokyo. He looked at a similar question for dimensions 5 and above. But the interesting dimension for physicists is 4, and then it is more difficult. When Blaine and I published the announcement of our result, we invited Jim to sign the paper with us. He was reluctant as he had not made a real contribution. At that time, Blaine had moved to Stony Brook. It was not so easy to convince Jim, because he had left mathematics a year before. He had inspired us, and therefore we felt having him sign the paper was appropriate. He finally accepted (see [6]). Later, I learned he found it nice that we invited him to cosign the announcement.

After that, I spent the spring of 1980 at the Institute for Advanced Study, for a special semester on global analysis. It was an incredible semester with Yau, Karen Uhlenbeck, Rick Schoen, Peter Li, Robert Bryant, Clifford Taubes and so on. Calabi would come to the institute very regularly, and it was really a fantastic period mathematically, just the moment where global analysis was exploding.

I then spent the fall in Stanford. There, I was supposed to work with Yau, but Yau had just moved to Harvard. Of course, being in Stanford was very nice, Peter Li was there. Although I could have considered staying longer in Stanford, we decided to return to France at the end of 1980.

These stays in the US have been mathematically extremely inspiring. Still, my wife and I, we never felt we could live in the US for good. It may be difficult to explain why. It really has to do with the way society functions. We are truly European.

Mathematical results and methods

MR: *I would like to ask you which of your results and methods you are most fond of? But perhaps you have already answered that question?*

JPB: There is another result [1], again a 4-dimensional one, which I like a lot: *"on a compact manifold with non-vanishing signature, a Riemannian metric with harmonic curvature, as a vector-valued two-form, is necessarily Einstein."* It is a nice combination of an analytic assumption and a global topological assumption, and the way these two interact is quite subtle. I got the basic idea during a year I spent in Bonn in 1976/77, but I was stuck for quite some time. Listening to a lecture on a completely different topic, I realised how to attack this missing algebraic lemma, which in fact is just an exercise. My hope then was that it might lead to new developments, although this has not happened so far.

In the meantime, the Calabi conjecture had been proved by Yau. I spent quite a lot of time checking the proofs, thinking, organising seminars and so on together with many people around Berger.

A lot happened then within global analysis, mainly thanks to Yau, Uhlenbeck, Schoen, and others. In 1979 at a conference held at the TU Berlin, I lectured on Einstein metrics and Ricci curvature [2] and proposed as a problem to consider the flow determined by the Ricci curvature in the space of Riemannian metrics. That's a reason why some physicists call the Ricci flow the Ricci-Bourguignon flow. At that time, I could not prove that the Ricci flow exists. Local existence was proved later by Richard Hamilton and Dennis DeTurck.

The end of the seventies has been an exceptional concentration of new ideas, new problems, an entirely new dynamics of the field of global analysis, and even a new name. I felt really in the middle of this because of the connections I had established.

Science administration

MR: *And you really seized the opportunities! But at the same time, you got involved in science management. How did that occur?*

JPB: I got elected as chair of the Mathematics Committee at CNRS when I was only 33 years old and still in the US. The function started only in 1981. That was not expected and *a priori* not very reasonable, but all the people who should have been elected for the function were not elected for various reasons. The choice fell on me. That resulted in an extraordinary opportunity to look much more broadly into mathematics and how to interact with scientists from other fields. My job as chair was to defend mathematics in front of physics and other subjects. At that time, I was still very young, and therefore, if I wanted to successfully push anything forward, I had to prepare twice as much compared to other more established people.

If I look back, it was certainly the time when I started to have a much broader knowledge of mathematics. I also found out that one actually needs to defend mathematics. This is not always a trivial exercise, partly also because of the attitude of some narrow-minded and sometimes arrogant mathematicians!

I started to get close contacts with scientists from other fields, looking for people who could support or help us. At that time, the chair of the Theoretical Physics Committee for CNRS was Louis Michel, a French physicist who was a permanent professor at IHÉS. He was very tough, and already highly recognised, member of the *Académie des Sciences*, and so on. I had some bitter fights with him. He defended theoretical physics, I defended mathematics.

Some ten years later, Michel was put in charge by the professors at IHÉS to look for a new director. His call to ask me whether I would be willing to consider becoming the director of IHÉS came as a huge surprise to me. I thought that could not work because I remembered our tough exchanges. But it was just the opposite, because he liked the way it had happened. I think this is psychologically interesting in the sense that he accepted that some people could defend other points of view and that he even valued it. Anyway, this opportunity came completely unexpected!

MR: *And the story goes on: You were president of the Société mathématique de France, from 1990 to 1992, of the European Mathematical Society from 1995 to 1998, director of the IHÉS from 1994 to 2013. And to the great satisfaction of the EMS Executive Committee – and of all mathematicians, I believe, you became the president of the European Research Council from 2013 to 2021, with a short interruption. And that happened after ordinary retirement age!*

You are still very active, among other things as member of advisory boards, for example in Germany, in Finland, in Denmark and in Ukraine. We certainly cannot cover all your activities. I am sure you need a special mind-set, a particular gift, in order to be successful as a top scientific administrator and politician?

JPB: After my period as chair of the CNRS Mathematics Committee, I was elected member of the Scientific Council of CNRS. This Council gathered a really interesting group of people, and it gave me new opportunities to interact in a very constructive way with non-mathematicians.

I became professor at École polytechnique in 1986. At that moment, mathematics at the universities in France was in big trouble: All vacant positions in mathematics were taken away to create departments of computer science. It was obviously important to establish departments for this emerging science. The idea that all positions for that purpose should be taken from mathematicians was stupid, but mathematicians did not know how to avoid that. For example, in the 1980s the mathematics department in Strasbourg could not hire anybody for about ten years, which is a killer.

MR: *You miss a whole generation!*

JPB: Yes. At that time, the president of the Board of Trustees at École polytechnique was a banker, Bernard Ésambert. After being elected as professor, I paid him a visit, telling him *"I think we need your help. French mathematics is in trouble, and we must get people outside the community to make the point."* He said: *"I'm willing to do that and help you find people in business who can make the case. But you will have to accept that the meeting to make the case should not be addressed to mathematicians alone, but much more broadly."* He helped me, together with a few other people, among them Jean-Francois Méla, the then president of the *Société mathématique de France*, to create an event which we called *"Maths à venir,"* which in French can mean "to come," but also if you join the last two words – "future." The meeting took place in November 1987, shortly before the reelection in 1988 of François Mitterrand as president of the French Republic. The event was an extraordinary success. We could convince famous mathematicians of the previous generation, like Jacques Dixmier and Henri Cartan, to be involved. The coverage in the press was fantastic, thanks to Méla who knew well the right people to connect to. Alain Connes gave an extraordinary lecture with non-mathematicians in mind. The advisor of the French president attended that lecture. I was in charge of taking care of him. When he left after listening to Connes, he said: *"we must help you, we cannot leave it like this."*

Then Mitterrand was reelected, *a priori* a piece of good news for us. Consequently, it was decided that a special directorship for mathematics would be created in the Ministry. Before that, mathematics had always been under physics. Moreover, all positions taken away from mathematicians to create the computer science departments were given back. Of course, not immediately, but over a range of 10 years.

In 1990, I became president of the *Société mathématique de France* a little bit by default, because nobody wanted to take the job, until it finally fell on me, and I accepted it. Not so clear, because at the time, I was in Zurich visiting the ETH for three months. There, I could talk to many people, and among them with Jürgen Moser, an exceptionally bright and deep mathematician.

The European Mathematical Society and the IHÉS

MR: *Did it not get complicated when the EMS was to be established?*

JPB: Certainly. The EMS was created in 1990 at a meeting in Madralin, close to Warsaw, at a difficult moment, shortly after the fall of the Berlin Wall in 1989. There was tension between the British and the French views. The Brits wanted the EMS to be a society of societies, whereas the French wanted mathematicians to be able to join the society individually. Discussions in Madralin were tough. And it took all the diplomacy of Hirzebruch, who had already been chosen to be the first president, to bring the two approaches to converge. When a compromise had been found, Michael Atiyah was then offered to become the member number 1 of the society! It was very nice on his part to accept that because the compromise was the opposite of what he said should be done!

MR: *The ice was finally broken! How long did the meeting last?*

JPB: It lasted two days, but the first day was quite violent! Even to the point that some colleagues from the UK said that if the French don't want to join the EMS as we propose it, maybe we set up the EMS without the French. But the Belgian and the Italian representatives and a few others had the same vision as us. It ended fortunately with a compromise, members could be societies and individuals. Because of this big tension back in 1990, I was very surprised when, in 1993, Hirzebruch called me, close to the end of his mandate, to ask whether I, one of the key troublemakers in Madralin, would agree on being his successor.

MR: *This sounds like the same story as the one with Michel and the directorship at IHÉS that you told me before!*

JPB: In a sense yes, but my personal relation to Hirzebruch had always been very good, although we never really worked together. He was such an amazing administrator and mathematician, of course, but also able to get things done in a very gentle way. For me, he has been a model in terms of management.

I started my mandate as EMS president in January 1995. At that time, I had already taken up the IHÉS directorship. I took this job one year later than planned because I had agreed to spend six months at MSRI in Berkeley in the spring of 1994, and I didn't want to give this up. I knew that being in charge of IHÉS would leave me less time to do mathematics! It was not very nice to Berger, who held the director position, because it meant he had to stay one more year against his intention.

These six months at MSRI were very interesting, as well. William Thurston was the director there, and the MSRI was going through some difficult times. For me, it was also a good opportunity to observe how such an institute functions. I went also to the theoretical physics Institute in Santa Barbara, now known as the Kavli Institute. That was also a great occasion to talk to people, find how they organised an institute and events.

This time was a learning period for me. But, when I started, I had not properly estimated how bad the financial situation at IHÉS was. Up to the point, that soon after having been hired in 1994, I had to fire myself because there was no money to pay me! That was not terrible, because I could just bounce back to my CNRS position. But it shows that the financial situation was really bad.

This convinced me that we had to look for new money urgently; the institute had not really worked on that option, but there was no other way! As a result, we started in earnest to try and find sponsors who would really bring new support to the Institute. Jim Simons had at that time not only switched from mathematics to business, but he had already become quite rich. He made his first gift to IHÉS on the occasion of his 60th birthday. At the end of the reception at his home next to Stony Brook, he told me, *"I think I never gave money to the IHÉS. Would $250,000 be good for you?"* I said, *"Of course!"* The first time we got money from Jim was just a gift at his initiative, I didn't even ask for it. He proposed it.

Later, at the conference for my own 60th birthday in 2007, at the beginning of his lecture he said: *"I made a mistake. At some point, I gave money to Jean-Pierre. Then he learned how to ask me for money!"* He and his wife Marilyn have been fantastic supporters of the institute. Without Jim's and Marilyn's support and advice, IHÉS could not have done what we managed to do; and their support continues to this day!

MR: *Generally speaking, you must have learned a lot on how to create trust in the first place, and then also to lobby for mathematics, for money but also for influence.*

JPB: In some sense, yes.

Pure and applied mathematics under one umbrella

MR: *What about the relations between pure and applied mathematics?*

JPB: Thinking back, the period from the mid-eighties to the end of last century was characterised by a very significant move forward towards applied mathematics and, at the same time, a broadened interest of other scientists for mathematics. I knew that first-hand concerning physics. But there was also biology moving forward, the importance of statistics grew very significantly. Rather than considering that applied mathematicians took away positions from fundamental mathematicians, it became necessary for mathematicians to cooperate as a global family. Already with *"Maths à venir"* and then as president of the *Société mathématique de France*, I had to make sure that the pure and the applied mathematicians could work together. We learned quite early that, without a common defence of our subject, we would not have a chance. I think, in France we were reasonably successful in this respect; in some other countries it took longer to arrive at that conclusion. For example, the opposition between pure and applied continued for quite some time in Germany. This is one reason why the creation of the new Max Planck Institute in Leipzig was important: its name is "Mathematics in the Sciences," the sign of a much more open approach. And there, the personality of Jürgen Jost, among others, fits perfectly with this vision because of the breadth of his work. He could reach out to many other fields, in particular biology, and even the humanities. This period has been very important for a broader approach by mathematicians, even if some still resent that. But I think this change was essential and justified.

MR: *If you look back, what were the most interesting issues? What were the obstacles? What do you consider as your successes as EMS president?*[1]

JPB: Well, Hirzebruch had already prepared the creation of JEMS, the Journal of the European Mathematical Society, even if it was finally put in place during my time. I convinced Jürgen Jost to

Four EMS presidents: V. Mehrmann (2019–22), J-P. Bourguignon (1995–99), M. Sanz-Solé (2011–14), P. Exner (2015–18) at the EMS 30 years celebration at the International Centre for Mathematical Sciences in Edinburgh

become the first editor-in-chief, which I think was a good move. That was a collective decision, of course. It became very important for the identity of the EMS that it would have a journal that was considered by mathematicians as a reference journal, and I think this has been achieved!

There were again some difficulties, because some people wanted to have it altogether focused on pure mathematics. I did not think this was the right idea, and we tried to allow a broader content.

At that time, a very substantial split between the pure and applied communities still existed in some countries. As EMS president, I had to understand the variety of situations and see how one could work on it and make people finally comfortable with the change of situation. Moreover, you must find people who have an attitude which is fundamentally respectful, open to discussion and not just defending their *pré-carré*, their (sometimes very small) comfort zone, an attitude which is for sure counter-productive.

This is also why it was important to make sure very soon there would be an applied mathematician as EMS president, and this is what happened. After a lot of discussion, because some people disagreed!

MR: *Rolf Jeltsch, a numerical analyst from ETH Zurich, became your successor!*

JPB: And Rolf's presidency has been a very successful one.

[1] More about the history of the EMS in [5].

Institut des Hautes Études Scientifiques (IHÉS)

MR: *Is the problem over?*

JPB: The danger of a clash between pure and applied is, I think, definitely over. I learned that already at the IHÉS, which was constructed as an institute bringing together theoretical physics and mathematics. The mathematics part was very pure; Alexander Grothendieck and René Thom were very pure mathematicians. Nicolaas Kuiper quickly appointed for example Jean Bourgain, who was fundamentally a problem solver, somebody with a quite different attitude. When Bourgain was hired, he worked mainly on Banach space theory, but Kuiper anticipated very quickly his fantastic capacity to contribute to harmonic analysis, using very subtle estimates, and using them also in several fields including number theory. In that way, the image of the institute was broadened by the kind of mathematics Bourgain was contributing to. During my directorship, Misha Gromov started to work on mathematical aspects of biology, and I tried to support him in that move. We did not hire a biologist as permanent professor, but the IHÉS organised several very significant conferences, bringing together mathematicians and biologists.

We also got closer to engineering. I am very glad that the visiting chair, which was created with the support of the Schlumberger company, allowed us to invite prominent scientists working at the interface of, e.g., mathematics and computer science, or mathematics and statistics. For example, Stéphane Mallat, who is now professor of data science at Collège de France, held this chair for one year. During his time at the IHÉS, he discussed, e.g., with Gromov; not exactly what you could have expected! Mallat had done great mathematics in wavelet theory before, and he even founded a company. But when his students wanted to celebrate his 60th birthday last year, they organised an extraordinary conference at IHÉS. Among the attendants, we had all the leaders in artificial intelligence worldwide.

These are some examples of the way I tried, during my time as director, to open the Institute and to show that there were other ways of doing mathematics which were important to stimulate new mathematics, of course discussing with the permanent professors and the members of the IHÉS Scientific Council.

Today, it is completely obvious that artificial intelligence (AI) will bring important developments. But Stéphane Mallat keeps saying that a difficulty with these very efficient algorithms is that we don't yet know *why* they are so efficient. From a mathematical point of view, it is not acceptable not to understand why this is so! That shows that there are still some pieces of mathematics missing that need to be developed and understood. Perhaps, new concepts or new approaches to analyse neural networks, the tool on which AI is built. We still don't have a theory of neural networks sophisticated enough to explain why they are so efficient.

MR: *A better understanding would give us a way to improve the applicability…*

JPB: Yes, but also to diminish the risk that you are fooled by what you see. The networks are efficient, perhaps for bad reasons. Unless you have understood something in depth, you cannot find the situation satisfactory.

MR: *It might be some sort of voodoo in the end…*

JPB: Coming back to IHÉS, we had to improve the facilities, which meant finding money for that, and thus stabilising the institution. Equally important for such an institute is to be able to attract the right people, the absolute best scientists that you can find and that are young enough, because the institute does not pay so high salaries. When they are very young, your offer may be attractive.

MR: *How would you do that, finding out who is really promising?*

JPB: There is quite some betting over it! You try and see and visit places where young people speak, and find out whether you are impressed or less so. You listen to people, and you ask other people for advice. I must say some fantastic mathematicians helped me a lot with that, Jacques Tits was one of them, I talked with him very openly, exploring who could be the next Grothendieck. André Haefliger was also very helpful. Their help was very much appreciated because they did not act as lobbyists. They did not defend their special area. They were just listening and observing. I owe them a lot! I also got help from some physicists from France and elsewhere. There was no reward for them, except perhaps the feeling that they could help the Institute continue to develop itself, and to promote the right people. Finding the right people at the top is a bet, and you can make mistakes. If you don't take risks, you have no chance of succeeding!

The European Research Council (ERC)

MR: *When you were about to finish the directorship of the IHÉS, you went on to become the president of the European Research Council. Again, an administrative job at the very top, but this time not promoting mathematics in the first place. You had to represent the entire spectrum of European science, including natural sciences, medicine, humanities, social sciences and so on. Mathematics is just a minor player in that game; there are not that many mathematicians compared to, say, biologists, or people in the medical sciences. That must have required something very special from your side, it must have been tough. Can you expand, please? Perhaps you can also give advice to mathematicians who want to apply to the ERC?*

JPB: Perhaps you don't know that after my time as president of the European Mathematical Society, I've been involved with a group of people who felt that scientists at the European level were not properly organised as a lobby. With the biologists in the lead, I was soon involved in the creation of the organisation called "Initiative for Science in Europe" (ISE). There, we dreamt of something like the ERC, but we did not know how to make it happen. ISE became for sure the main lobby for the creation of the ERC.

And then I was also directly involved in the creation of the association EuroScience in Strasbourg. It was in fact an outgrowth from a small committee set up by CNRS to develop its relations with Europe altogether. And there I met many people who later became very crucial at the ERC level. For example, I met for the first time Helga Nowotny, who then became the second president of the ERC Scientific Council. My involvement with scientists in Europe from other disciplines dates back to the late 1990s and the early years of this century. Moreover, I was a member of the Scientific Committee of several EuroScience Open Fora (ESOF) until I became the ERC president. I withdrew to avoid any conflict of interest.

I had been involved with all these people from different countries, different disciplines, different approaches for quite some time, and it was another component of my life as a scientist to talk to these people. I developed an interesting network with the common aim of helping to promote science at the European level.

I also came in touch with another person who played a very important role in European science, José Mariano Gago, by a random coincidence. Gago was a physicist who was the Minister of Science in Portugal several times. He decided that Portuguese science had to be evaluated internationally. He looked for people who would be willing to participate in such evaluations, discipline by discipline. I became a member of a committee in charge of evaluating Portuguese mathematics several times. The chair of that committee was Irene Fonseca, a Portuguese mathematician working in the US – she is currently vice-president of the AMS. During this time, while being the director of IHÉS, I became a friend of Mariano Gago, and he would call me asking for advice. He then became the key actor for the creation of the ERC, jointly with Philippe Busquin, a former Belgian Minister of Education, who became the European Commissioner for Research, Science and Innovation at the turn of the century and who really fought for the creation of the ERC. Reaching that stage was quite difficult since several of the big countries were not in favour. Germany was against it, France was neutral. It was the smaller countries: Denmark, Sweden, the Netherlands, Ireland, Austria, that felt that a European Research Council could make a positive difference for them, and for Europe as a whole. The key meeting took place in Dublin in 2005, under the Irish presidency. It was the last-minute change of mind of a Minister of a large country that made the creation of the ERC possible. I then became the first chair of the ERC panel for starting grants in mathematics, and that was a wonderful experience. The panel members really wanted to hear about mathematics!

Some people seem to believe that I prepared my presidency during this time, but not at all! Of course, I monitored how the ERC evolved. Still, I could not know how its further development could involve me at some stage. Actually, the EMS played a very important role in my decision to accept to be nominated for the president post. The only way to become a candidate was to be nominated by institutions. Marta Sanz-Solé, the EMS president at that time, called me and asked me to submit my CV as a sign of my interest to be a candidate. I answered: *"Marta, I have already plans for my next year, from 2013 until the fall of 2014. And sorry, unless you find other people who want to nominate me, I will not submit my CV."* Then a few days before the closure, other supporters had been found, among them, EuroScience and the CNRS.

Finally, I had to consider seriously whether I was interested in being considered for this job. Indeed, in September 2013, I finished being the IHÉS Director, having reached the retirement age for CNRS. I wanted to leave a free space to act for my successor Emmanuel Ullmo. For that purpose, my wife and I had planned to spend the entire 2013/14 academic year travelling around the world, spending three months in four different places. We wanted to start in Stanford, and then to travel to New York, Hong Kong, and Beijing. And, each time, we would be accompanied by one of our grandchildren. We had four at that time. Since the probability that I be chosen was quite limited, I decided to send my CV in March 2013. The selection process then developed. I was first selected by the search committee to be interviewed, then among the three finalists to be interviewed by the ERC Scientific Council, and the Commissioner on 4 July. Suddenly, all our plans with the grandchildren were collapsing! We were only able to take two grandchildren with us for the first three months in Stanford. They went to an American school, and it was a wonderful experience for us as grandparents, and, I believe, also for them. The other two grandchildren are still frustrated that they couldn't travel with us.

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MR: *Understandable! I still remember the great applause in the Executive Committee of the EMS when we were informed that you were, in fact, chosen as president.*

JPB: It was a surprise to me. I only wanted to be at least interviewed by the selection committee. Otherwise, it could have meant that the people who supported me had made a wrong choice. I was quite surprised to learn that I was proposed for the position. The French Minister called me and told me I was one of the three finalists! She had just been informed by the Commissioner. I happened to be in New York at the time. And I realised that I may have to change my plans.

These years at the ERC have been fantastic: The contact with high level scientists of all kinds, and the staff at ERC was extraordinarily gratifying.

MR: *Did you have to move to Brussels?*

JPB: Oh yes, I had to. It was part of the duty. I was very lucky because Commissioner Carlos Moedas with whom I had to interact was remarkably trustworthy. We had a very direct, simple relation. We did not agree all the time, but that was not the point. He would listen to me and respect me, and I would respect him also. He is an intellectually brilliant man, now the mayor of Lisbon. I was very lucky. The Scientific Council, too, was composed of very good people.

The bad news was that my successor failed, and he was then asked by the ERC Scientific Council to leave after only three chaotic months. It still puzzles me that it could not be spotted from the outset that nominating this person was risky!

MR: *And you had to carry on for another year!*

JPB: That is what happened, not expected either! My wife was not very happy, I can tell you. It happened during the pandemic, and I stayed home, spending almost all my time in front of my computer. The pressure was considerable in the fall of 2020 because of the financial negotiations for Horizon Europe that were taking place with the European Parliament (EP) and with the Commission. I used the network I had built there over time. I could quickly connect to people despite the pandemic. The original budget of Horizon Europe was very disappointing; the EP managed to increase it a bit, still not as much as we would have liked.

The support given by the ERC staff has been wonderful. I have been in contact with many agencies in the world during my professional life. I must say that the ERC staff are of a very special kind, highly professional and committed. They know how to work together. I enjoyed this environment a lot.

It was more difficult to cooperate with some people on the Commission side. Staff there is on average also of high quality. Still, they are often afraid of making a mistake. They tend to be very conservative and want always to make sure that nobody can have serious objections to anything they propose. This is of course not the right atmosphere. Also, I must say that many refuse to accept the idea that science and research function in a certain way that does not necessarily follow the general rules, and that was often frustrating!

MR: *They are absorbed by legal questions, right?*

JPB: Yes, they want to protect themselves. The idea that the ERC is under the responsibility of the Scientific Council is unbearable to some of these people.

MR: *Do you think mathematicians exploit the ERC well enough by now?*

JPB: Not really. There are not enough mathematicians applying. Many mathematicians have not understood that the ERC was built for the scientific communities. The panel that judges your application consists of experts from your field. Many mathematicians think that the ERC grants are too large. This is not the rule of the game. People should ask for the right amount of money for what they want to do. The people who are going to judge your application are your colleagues; they know what is relevant for your project. When you ask for too much money, it's not going to be a good point for you. I know that institutions sometimes press people to apply for more money because they get their share. You should resist, you should make a proposal which is adequate for your project.

When ERC started in 2007, the amount of money going to mathematics was almost equal to the amount going to computer science. Now the ratio is 1 to 2. And the growth of the two communities has not been 1 to 2. Mathematicians are not taking enough advantage of the ERC. The amount of money given to an ERC grant for a mathematician is typically about half the maximum amount. The amount is probably relevant! Some projects need more money, others don't need that much. For many institutions, just having an ERC grant makes a difference in terms of visibility and respectability. Much more than the amount of money! I kept repeating this, but I don't think I've been successful in delivering the message; perhaps I didn't say it in the right way.

MR: *Well, then it is good to have it repeated here.*

Ukraine

MR: *Can we move on to a different subject? The European continent is right now shaken, to put it mildly, by the war in Ukraine. Historically and in the near past as well, Russian mathematicians* *and Russian mathematics have been very important and influential. Ukrainian mathematicians urged the EMS to suspend all relations with Russian mathematics. The EMS suspended only membership of the Russian mathematical societies which are under direct state influence and financing. Was that the right decision, in your opinion?*

JPB: Very complicated! There have been statements by rectors of some Russian universities supporting the invasion, and this is totally unacceptable to me. Still, it is extremely important that scientists, on a personal basis, continue to keep contact with their colleagues. The learned societies are, in a sense, in between. Depending on the way they are set up and operate, it may vary very much from one country to the next how they are related to political power. One must check very carefully, on an individual basis, whether a learned society is in fact independent or not.

MR: *You are also personally engaged helping Ukrainian mathematicians.*

JPB: I must say that the way Ukraine defends itself is extraordinary. Nobody would have thought they would be able to do that when Russian troops started the invasion! The price they pay is so high. The war is still ongoing, it costs many lives, and that is terrible. At some point, the war will end. Ukrainian scientists considered what will happen then. Reconstruction might be slow and complicated; the damages will probably continue to affect the daily life of many. The support of science might not be the priority. To create better conditions for Ukrainian mathematicians, they developed the idea to create a place, an institute, allowing communication of mathematics at the highest possible level within the country. This is how the idea of ICMU, the International Center for Mathematics in Ukraine, came. This institute should give young people, in particular, the possibility of continuing to do high level mathematics in the country. It is to the mathematicians in Ukraine to determine how the institute will function. My role is to help them find money to establish the institute.

MR: *You are on the Supervisory board.*

JPB: Yes, I am chairing the Supervisory board, which, under Ukrainian law, is the equivalent of a Board of Trustees. So far, we have not been as successful as I hoped finding resources. So, I am a bit disappointed. The French government responded to my expectation, granting €200,000 to ICMU, which was the amount we requested. Recently, the Klaus Tschira Foundation committed €100,000 and possibly more through matching. Presently, we continue looking for help from some other governments and from some foundations.

Jørgen Ellegaard Andersen from Denmark is helping me in this endeavour in his country, similarly other mathematicians do the same in other countries in Europe. The key actors are of course Ukrainian mathematicians. Masha Vlasenko at the Polish Academy of Sciences in Warsaw and Maryna Viazovska at École Polytechnique Fédérale de Lausanne are particularly active and engaged; we talk to each other regularly. Compared to their and that of their colleagues, my contribution is very small. I have some experience looking for money, and I would have hoped to be much more efficient than I have been so far.

The fight is not over! I think their view is correct, they must be able to show to young people, that, even if you stay in Ukraine, there is a possibility to be properly connected to high level mathematics worldwide.

MR: *What is the long-term vision for ICMU? Will it be a centre where people come to visit for a certain period of time?*

JPB: The model they chose, which I think is correct, is that of the Isaac Newton Institute in the UK, or the Centre Émile Borel in France, or the Simons Laufer Mathematical Sciences Institute (former MSRI) in Berkeley in the US. ICMU will organise periods, from three to six months, on a topic that visitors and the local people concentrate on. That is what the Ukrainians want to achieve.

And they still need a place which is suitable for this purpose. To organise events, they will obtain support from various societies and foundations. For example, the London Mathematical Society just agreed to support some events. I am confident that they will be able to secure some money for each event in the future.

Mathematics throughout the world

MR: *In our lifetime, mathematics and mathematicians from so-called 3rd world countries have become far more important. China, India, and Brazil are awe-inspiring examples. And that development is certainly to continue, right?*

JPB: We must be very careful with the expression 3rd world. I think that China is not a secondary player at all in many scientific domains; in mathematics, China is even a leading player now, actually very important for mathematics worldwide. That has to do with the country's size, with its long-term investments, with the commitment and the quality of its scientists.

India is a bit different. It has also a very long tradition and, of course, there are lots of things happening in Indian science. The country is also moving forward, but not uniformly. Brazil is also mathematically a very important country, even if, in recent years, the situation has been difficult for many reasons.

Another continent that I've been involved with for quite some time is Africa, where the situation is complex: some countries made very significant progress, and some others face very difficult political and economic situations, with the effect that many scientists, particularly mathematicians, moved away because it was not possible any more to live there safely.

I chair the Scientific Council of an institute in Benin, the *Institut de Mathématiques et de Sciences Physiques* (IMSP) in Porto-Novo. Actually, its founder, Jean-Pierre Ezin, has been my first PhD student and was the first Beninese to get a PhD in mathematics. Later, he became for some years the African commissioner in charge of Research and Higher Education. The IMSP runs a very significant excellence programme financed by the World Bank. A lot of students come there from many other African countries. They have made fantastic progress in terms of the quality of the training. Still, some practical things can turn out to be difficult. For example, they have a hard time spending the money they have because of extremely restrictive administrative rules that need to be followed to prevent corruption. Unfortunately, this programme comes soon to an end, and it is not clear whether it can be continued in some way, although it has achieved remarkable results in the training of high-level African scientists.

The Role of education

MR: *You have often stressed the importance of quality education, from pre-school to tertiary education, in mathematics and other subjects. In your view, what are the best strategies to provide and improve numeracy and curiosity towards mathematics among young people?*

JPB: This is a very critical issue. And unfortunately, in recent years in the Western world, we rather observe a regression, and especially in France. This is related in particular to the difficulty to attract good teachers, certainly for mathematics. There are now so many companies who want to hire people with a high level of competence in mathematics and who offer far better salaries than those offered to teachers. Salaries of teachers depend a lot on the country. I recently checked that Canadian teachers were quite well paid on average: a beginning salary of a secondary school teacher in Canada is 44% higher than in France, and the end salary is even much higher! So it is no wonder that one has difficulty finding good teachers. Moreover, the job has become more difficult than it was in the past. That's what my sister, who retired after having been a maths teacher for all her career, tells me: her last years were quite difficult.

We must recognise that for kids access to information outside school has grown a lot. If you want to know about something, you just take your phone, and you get the information. Still, if you want to receive it in a proper way, you need to be trained to check that the information is valid. At least in France, school is not designed to teach you that. We probably need to rethink in depth how a school can be organised and what the optimal role of teachers in this context is, because the situation has changed radically.

In France, 80% of the primary school teachers have no scientific training whatsoever. Of course, the Ministry trains them to teach basic science, in particular basic mathematics. Now, if the teacher gives the kids the feeling that what they are being taught in science or mathematics is difficult, the kids will consider it to be difficult, even if it's quite trivial. Not only the content is important, but also what kind of feeling, what kind of enthusiasm you convey, what kind of approach you take. We all know that what made the difference to almost of us are teachers who really gave us the feeling that what they were telling us was important.

The main difference between Asian countries and Western countries at this time is the importance that parents attribute to the training in science. It makes a big difference for the kids if they know that their parents care. They don't behave the same way if they have the feeling that no matter how they behave, the parents will support them.

I think dealing properly with the education issue is extremely important. Things are changing quickly. Just imagine the possible impact of ChatGPT on school evaluation. How can you give homework exercises when these tools are available? How can you be sure that the kids have done the work themselves? We must rethink the situation collectively; it is not just mathematics. One certainly must put a lot of thinking into that; however, I do not see it happen, at least in France! This is very important! The countries which really progressed spectacularly worldwide in recent years are those which have put education as a top priority for many years. South Korea is an excellent example.

Outreach

MR: *Outreach activities are important for the mathematical community; you have contributed yourself substantially. Can you mention some examples, offer some advice, please?*

JPB: This is connected to my own interest in Art, although I am not an artist. On some occasions, I had the opportunity, often by coincidence, to be in contact with people in the world of Art. Here is an example: The world-famous Japanese photographer Hiroshi Sugimoto made an exhibit at the *Fondation Cartier pour l'Art Contemporain* in Paris showing a collection of photographs of mathematical shapes from the University of Tokyo. These were huge pictures. For a reason still not clear to me, the Foundation called me saying that Sugimoto had been told that I would be the right person to help write the catalogue. I did not know him then. The catalogue was designed in the following way: on the right page, you have a picture he made of a certain surface, and on the left page, he wanted to have an equation for the surface, and explain why it is interesting mathematically. I wrote that part. That was my first contact with him; later, we became friends. I visited his ateliers in New York and in Tokyo. His companion has a wonderful gallery in Ginza. This connection came really out of the blue!

Before I had visited the *Fondation Cartier* a few times privately, but this association made me become a friend of the director, Hervé Chandès. At some point, he called me to say that he wanted to stage an exhibit on mathematics. That was the starting point for the exhibit whose English title is *"Mathematics, a Beautiful Elsewhere"* – in French it was called *"Mathématiques, un dépaysement soudain,"* a title borrowed from Grothendieck, by the way. This exhibit was not about mathematics *per se,* but rather about the reciprocal fascination that can arise between artists and mathematicians. I helped identify some mathematicians who could contribute. It was an extraordinary experience because the artists were leading ones, and the mathematicians were also prominent figures.

Some people disliked the exhibition, saying that it was telling nothing about mathematics. This was just not its purpose! The exhibition had 80,000 visitors, in line with the usual number of people visiting exhibits at the *Fondation Cartier*. It had also some follow-up events outside Paris: for example, the *Fondation Cartier* showed an overview of several of its exhibits, among them this one, in Shanghai. I just happened to be passing by, and there I could watch again a movie by another famous photographer, Raymond Depardon, which is part of the exhibit, featuring Sir Michael Atiyah, Mikhael Gromov, Don Zagier, Nicole El Karoui and myself!

This has been an extraordinary experience which I enjoyed a lot. Gromov contributed very significantly; in another follow-up, he participated in a radio show on one of his books explaining what he considers key important mysteries in science, in relation with what he showed at the exhibit. This book has been very successful in France; in English it is entitled *"Great Circle of Mysteries: Mathematics, the World, the Mind."* All this was not planned at all, it just developed, taking advantage of the right actors around.

Another such instance came around with the documentary movie "*How I came to hate math"* by Olivier Peyon, mixing French and English. My contribution was to take Olivier to various places where mathematicians gather: the ICM in Hyderabad, MSRI, Oberwolfach, IHÉS, and so on, to give him the opportunity to meet mathematicians and to get a view on how mathematicians communicate. The movie also contains a long interview with Jim Simons, who just passed away and to whom I owe so much. Getting money to shoot this documentary was very difficult. But in the end, perhaps the producers who made the movie earned some money. For sure, that experience was totally unexpected! Jointly with the film director, Olivier Peyon, I have participated in the promotion of the movie in several places in France and Belgium. Each time, it gave rise to an interesting exchange with people in the room, very often parents of school children.

MR: *What about the EMS Diderot Fora?*

JPB: The fundamental idea behind Diderot Fora going back to the time I was the EMS president was twofold: to establish a format adapted to Europe different from big conferences, and to show important connections between mathematics and other human activities. These events were held in three different European cities and, in each of them, a small meeting would be organised. The three places could exchange and communicate with each other by video conferencing; a few years ago, this was of course more difficult than it has become now! Some of these Fora have been very successful, others less so. Mireille Chaleyat-Maurel has been instrumental in getting the Diderot Fora develop. Among the very successful ones, we had one on *"Mathematics and Music"* organised in Vienna, Paris, and Lisbon. In Paris, it happened at IRCAM, the institute of Pierre Boulez, and it led finally to the creation of a mathematical team at IRCAM combining mathematics and music in some unusual ways. The key person, Moreno Andreatta, is now a CNRS fellow and has moved to Strasbourg. There is still a group of researchers at IRCAM on this theme as a direct consequence of the Diderot Forum; a far bigger and longer impact than could have been anticipated.

After a rather long break, Diderot Fora have been recently revived: one was organised on *"Mathematics and Architecture"* in Helsinki, Porto and Prague, and was very interesting. The format is again very relevant now with the travel restrictions.

Let me talk about another outreach effort, which I like very much: during my time at ERC, I insisted that we should communicate about the programme in non-conventional ways. It was not easy to convince people to do that. We opened a call inviting submissions of proposals on how to talk about research projects differently. One proposal that came in suggested using web-based comics or cartoons. And that has worked fantastically well! I can say that with conviction, because several artists who designed a web cartoon continued to cooperate with ERC scientists after the web-comic was finished. Both sides appreciated that it brought them something different. Some of these cartoons have been printed and participated in one of the key festivals for cartoons, in Angoulême in France. When I left the ERC, I got prints as a present. I know that the teams of designers behind these cartoons found it was a very inspiring experience.

MR: *You are not only good at seizing opportunities when they arise out of the blue, but also at opening new opportunities!*

JPB: Well, this approach could have failed just as well, you never know! People in the ERC communication team were afraid that we would appear foolish, that the image projected would result in people not considering these projects as serious. Some of the cartoons were very creative, they allow you to approach research in a quite different way. I really enjoyed doing these things, in collaboration with very special people. We mathematicians tend not to be open and daring enough, we are too afraid of failing. You must take outreach literally!

Family is important

MR: *I would like to come to an end with the same question that Christian Skau and I often had as the last one to the Abel Prize laureates. Forgetting about mathematics for a moment, would you please describe your main private interests, what is at your heart?*

JPB: My wife and I have three children and six grandchildren. We talk to our grandchildren quite a bit, and that has been and is very important for our life. My wife has been fantastically patient because I tend not to know what vacation means. It is important for the family that you sometimes stop being a professional, but I am very bad at that! Right now, my wife complains, rightly, that I am doing too many different things. When I was supposed to retire, I then became the ERC president, and this was one of the most intense periods of my life. She was with me in Brussels at the beginning. After some time, she realised that I was travelling so much that it didn't make sense for her to be alone in Brussels. The family, the grandchildren were then in Paris, and she decided to return to Paris. My years at ERC were actually six tough years, particularly at a moment in life where time starts to move forward faster than earlier.

Our parents have also been very important to us. We were very close to them. After my mother died, my father lived alone, and I would travel almost every weekend from Paris to Lyon to see him and relieve the pressure on my sister, who was living next door. That was quite easy, I was still at IHÉS and could use fast train connections. My parents have been very inspiring for me, and therefore accompanying them in the last part of their life was very important for me.

The grandchildren, too! One of our sons now lives in Berlin, and we go to Berlin every three or four months for at least a week. My grandson wants me to take him to school. He speaks French with his father, Turkish with his mother, who is Turkish, German because he goes to school, and he understands some English, because the parents speak English to each other. He is only seven years old; I find this amazing! Exchanging with my grandson in French or German is very enjoyable. Unfortunately, I do not speak Turkish, which is a great language.

Travelling

What I found wonderful about our profession is the number of friends we could make across the world. Friends with whom we exchange on a regular basis and whom we know very personally. I consider this a fantastic privilege. During my professional life, I had the opportunity to visit Asia many times, and I appreciate that very much. Professor Chern invited me many times in Tianjin at Nankai University where he retired, a great present! Another one is the great interview he gave me in 1990 [3, 4].

My last visit to China in July 2023 was my 43rd visit to China, and my last visit to Japan in April last year was also my 43rd visit.

Bourguignon lecturing at the Chern memorial, 2011.
(Photo: Chern Institute, Nankai University)

My wife also likes visiting these countries very much. We celebrated our 50 years of marriage by taking a one-week leisure trip in China, with the good surprise to discover that, at some stops, some of my former Chinese students managed to get our schedule and welcomed us.

I have also been to Korea quite a bit. Korea is a country that many European countries should learn more from. The Korean society has changed extremely quickly, and the main instrument has been education. For example, Korea was for a long time the country in which the division between men and women was the toughest in the whole world. Now, Korea is the country in the world with the highest proportion of women in tertiary education.

MR: *Interesting, I did not know that.*

JPB: Due to absolute priority given to education for sixty years. Even though the governments during that period were not always that friendly, still they kept an absolute priority on education. This shows how education can change a country, and we should learn from that.

MR: *Some final words?*

JPB: In short: Very often, people believe that you must have a strategy and follow it. Things never happened for me like that. The lesson is: if an opportunity comes to you, seize it! Sometimes, you may take a wrong decision, but opportunities will not come twice. And, as important, you must be open to other people, even to people who are less open-minded in the first place, there might be possibilities for convergence later. Even if you do not expect them, they may just happen, and you must then seize them!

MR: *I am very grateful that you offered two hours of your time, and that you gave us insights into your life and into your priorities in a very open way.*

JPB: You and the EMS are the ones to be thanked for the opportunity!

References

[1] J.-P. Bourguignon, Les variétés de dimension 4 à signature non nulle dont la courbure est harmonique sont d'Einstein. *Invent. Math.* **63**, 263–286 (1981)

[2] J.-P. Bourguignon, Ricci curvature and Einstein metrics. In *Global differential geometry and global analysis (Berlin, 1979)*, Lecture Notes in Math. 838, pp. 42–63, Springer, Berlin (1981)

[3] J.-P. Bourguignon, Entretien avec un optimiste, S. S. Chern. *Gaz. Math.* **48**, 5–10 (1991). English translation: Shiing Shen Chern, an optimist. In *Chern – A great geometer of the twentieth century*, Monogr. Geom. Topol., pp. 261–267, Int. Press, Hong Kong (1992)

[4] J.-P. Bourguignon, Shiing-Shen Chern – If possible do nothing. Video interview, Los Angeles (1990) https://youtu.be/vConuqi5vT0

[5] J.-P. Bourguignon, Taking the long view. In *Thirty years of EMS*, pp. 7–29, European Mathematical Society, Helsinki, Finland (2021) https://euromathsoc.org/thirty-years-of-ems

[6] J.-P. Bourguignon, H. B. Lawson and J. Simons, Stability and gap phenomena for Yang–Mills fields. *Proc. Nat. Acad. Sci. U.S.A.* **76**, 1550–1553 (1979)

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Rolf Jeltsch: A visionary in service of the mathematical community

Volker Mehrmann

The mathematical community in Europe and all over the world has lost one of the most prominent representatives. Rolf Jeltsch (1945–2024), former president of *Leonhard Euler Center*, *Swiss Mathematical Society* (SMS), *International Association of Applied Mathematics and Mechanics* (GAMM), *European Mathematical Society* (EMS) and the *International Council for Industrial and Applied Mathematics* (ICIAM), passed away on 28 June 2024.

It is extremely hard to describe the personality and life-time achievements of Rolf Jeltsch as he deserves. Let me start with his service for the community, which is best described by the statement:

> *In permanent service for the mathematical community locally, in Europe and worldwide, with particular emphasis on the unity of mathematics.*

While in many parts of the world there is a strong division between 'pure' and 'applied mathematics,' in some countries even with different mathematical societies, Rolf Jeltsch was always convinced that this division is harmful for the mathematical community and its global position in science and education. Such tendencies to split were also present in the global European mathematical community in the 1990s. Rolf always opposed such a split and with his leadership strength, he was certainly an ideal person to make sure that such a split did not happen. With this in mind, he was asked to become president of EMS. After a first hesitation, he accepted. He initiated a meeting of the presidents of the member societies that led to the 2001 Berlingen Declaration.[1] The declaration states a list of criteria for the future development of the EMS, and then during his presidency Rolf worked extremely hard for these criteria to be implemented.

Let me summarize a few of the points from the Berlingen Declaration: Pure and applied mathematics should both be represented well in the bodies and publications of the EMS. The EMS should invest in the future of the next generation of mathematicians, with its summer school program, and with an increased activity towards public awareness as well as mathematical curricula in school and at universities. The EMS should gradually introduce special

Rolf Jeltsch as president of GAMM at the annual meeting in Zürich.
(by courtesy of the GAMM)

interest groups and become active in influencing the developments in European science politics and international mathematical organizations.

If one looks back at the past 20 years, a lot of the goals of the Berlingen Declaration have been achieved, although it took a lot longer than anticipated. The division between 'pure' and 'applied mathematics' is not made any more officially, but from my own experience it is often still in people's minds. Moreover, the under-representation of countries from some regions of Europe still persists in the EMS committees, EMS prizes, and invited speakers. The gender balance is also far from ideal. But everywhere the gradient for change is positive, and in all these developments Rolf was a driving force. He had to overcome a lot of obstacles, because some mathematical societies were against changes, and it took someone like Rolf to get people out of their comfort zone. I have been very close to Rolf and his way of doing things for all my career and I could tell many stories that illustrate this.

A typical example of this happened during Rolf's presidency of GAMM, which had the rule that every past president was a life-time

[1] https://euromathsoc.org/about-berlingen-declaration

member of the executive committee. This had the effect that almost any suggestion to change something essentially was blocked. Rolf initiated a committee for the future of GAMM, and then managed to get the by-laws changed in this respect, with him being the first past-president who lost his life-time membership. After this, GAMM became substantially better prepared for the future and many of the developments in the EMS (like the young academy or the topical activity groups) are modelled after those established in GAMM.

Another major focus of Rolf's work for the mathematical community was the scientific publication business, which already 25 years ago was clearly moving in the wrong direction, with enormous profits for commercial publishers and at the same time a strong decline of publication and scientific quality, due to the instalment of article processing charges and the occurrence of predatory journals. I remember Rolf foreseeing these developments and strongly urging that mathematical publications should be in the hands of the mathematics community, i.e., mathematical societies.

So Rolf got going and initiated the foundation of an EMS publishing house. He organized seed money from ETH Zürich and worked hard to move some top journals like JEMS to the EMS publishing house. He hired a highly proficient director with Thomas Hintermann, and the whole operation became a success story that is continuing with the successor community publishing house, EMS Press, established after Thomas Hintermann retired. Not only is EMS Press financially doing well, but it has now moved all its journals to a subscribe-to-open model and in this way demonstrates that open-access publishing can be done successfully without article processing charges. The last time I talked to Rolf he was immensely proud of this development, even though he regretted that applied mathematics is still not represented well in publications of EMS Press.

After his successful presidency terms at GAMM and the EMS, he moved on and became president of ICIAM, the International Consortium for Industrial and Applied Mathematics, which organizes the world's largest mathematical congress. ICIAM congresses involve mathematicians on all career levels and is less focused on a large number of invited talks. The participation numbers speak for themselves, e.g., Rolf organized the ICIAM congress at ETH Zürich in 2007 with more than 3000 participants, an organizational masterpiece.

Why was Rolf so visionary and so extremely successful?

First of all, he was a very hard worker. Once he was convinced of a goal to achieve, he had the skills and persistency to get things done. He was very open to network and communicate with colleagues from all areas of mathematics, but also from science and engineering.

These skills were definitely a big part of his academic career that began at ETH with the diploma in 1969, the teacher's exam in 1970, and the PhD in mathematics in 1972. He had postdoc periods at Dalhousie University and UCLA, followed by an associate professorship at University of Kentucky. From my own experience, such long-term scientific stays overseas and learning about the way things are done in North America compared to Europe definitely widen the horizon in many different ways. Rolf's open-mindedness towards other scientific domains and cultures as well is visible in his later position he held at Ruhr University Bochum, RWTH Aachen and after his return to ETH in 1989. He was very much involved with interdisciplinary teaching and research projects with colleagues from engineering, and a driving force in the establishment of the interdisciplinary program 'Computational Science and Engineering' at ETH.

In his research work Rolf Jeltsch is well known for his contributions to the analysis and numerical solution of partial differential equations. His research topics involved the treatment of compressible fluids and magneto-hydrodynamics, where his focus was, in particular, on the stability of numerical discretization schemes for these classes of problems.

After mentioning all his great achievements, I would also like to mention Rolf's personality in supporting young researchers (like me back then) on their career paths. One could always ask him for advice and, although being very busy, he would help. All this on the other hand would have not been possible without the support of his family, especially his wife Marianne and their four children.

Rolf, thank you very much for all you have done for the mathematical community, we will miss you!

Volker Mehrmann received his diploma in mathematics in 1979, his PhD in 1982, and his habilitation in 1987 from the University of Bielefeld, Germany. He spent research years at Kent State University in 1979–1980, at the University of Wisconsin in 1984–1985, and at the IBM Research Center in Heidelberg in 1988–1989. After spending the period 1990–1992 as a visiting full professor at the RWTH Aachen, he was a full professor at TU Chemnitz from 1993 to 2000. He was full professor for mathematics at TU Berlin until his retirement in October 2023.
He is a member of Acatech (German Academy of Science and Engineering), the Academia Europaea, and the European Academy of Sciences; he was president of GAMM (Association of Applied Mathematics and Mechanics, Germany), and, until the end of 2022, president of the European Mathematical Society (EMS). He was chair of the Research Center MATHEON.
Volker Mehrmann is a SIAM and AMS fellow, has held an ERC Advanced Grant, and also was member of the ERC Mathematics Panel. His research interests are in the areas of numerical mathematics/scientific computing, applied and numerical linear algebra, control theory, the theory and numerical solution of differential-algebraic equations, and in energy based mathematical modelling.

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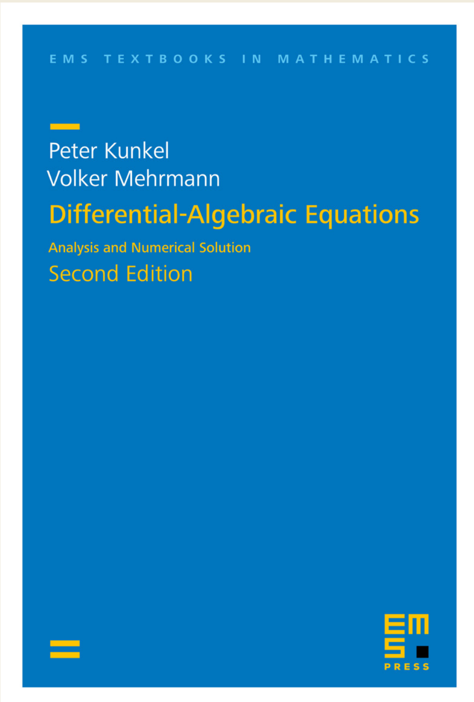

Peter Kunkel (Universität Leipzig)
Volker Mehrmann (Technische Universität Berlin)

Differential-Algebraic Equations
Analysis and Numerical Solution
Second Edition

EMS Textbooks in Mathematics
ISBN 978-3-98547-016-7. eISBN 978-3-98547-516-2
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Should mathematicians worry with PISA and TIMSS math results?

Nuno Crato and João Marôco

Since the end of last century, international large-scale assessment studies have been providing systematic information about countries' education results. The news they convey regarding European education are not at all reassuring and have worsened with school closures and the disruption due to the recent Covid-19 pandemic. The size of the education losses and the distance of most European countries to other areas of the world, namely South East Asia, are often overlooked. A simple statistical analysis shows most European students are about one to two school years behind their peers in most advanced countries and regions, and the gap is increasing. These facts will negatively impact European workforce, economic competitiveness, and development. They will most likely also negatively impact mathematics higher education and research in our continent. To recognise the problem is the first step to cope with it.[1]

International education studies results

Every four years since 1995, the IEA (International Association for the Evaluation of Educational Achievement) is organising the TIMSS (Trends in Mathematics and Science Studies) survey involving dozens of countries and assessing 4th and 8th graders in mathematics and science. The IEA later developed other studies for assessing other education areas and skills, e.g., reading. In 2000, the OECD (Organization for Economic Cooperation and Development) started the PISA (Programme for International Student Assessment) studies, regularly assessing 15-year-old students in many dozens of countries. PISA assesses mathematics, reading, science, and another selected rotating domain for each wave. It is held every three years, but the pandemic delayed the last one, which was held in 2022. We thus have a time series of more than 20 years, which allows us to compare performance and evolution of countries. Both PISA and TIMSS also report many data on students' background and teachers and school variables. PISA, TIMSS and most other international survey results are reported on a scale with average 500 points and standard deviation 100. However, due to long-term declines, the current average no longer corresponds to 500 points. Some 690 000 students took the PISA assessment in 2022, representing about 29 million 15-year-olds in the schools of 81 countries and economies. PISA students are aged between 15 years 3 months and 16 years 2 months at the time of the assessment, and they have completed at least 6 years of formal schooling. Using this age across countries and over time allows PISA to consistently compare the knowledge and skills of individuals born in the same year who are still in school at age 15, despite their diversity. They can be enrolled in any type of institution, participate in full-time or part-time education, in academic or vocational programmes.

The OECD publishes very detailed analyses on PISA results. At this moment, there are already five volumes of the technical report (2000–2022) and four volumes on related PISA 2022 subjects [6]. The microdata will be accessible in a few months' time, but the available data and reports are already very rich and very detailed. Table 1 shows the average PISA mathematics literacy scores for selected European, North American and South East Asian jurisdictions.

PISA 2022 findings showed a major drop in knowledge and skills in Europe as measured by the OECD PISA tests. This drop is larger in mathematics (−18.8 score points) than in the other main PISA areas, i.e., reading (−14.2) and science (−4.6). The fall in European results is in line with that in North American countries, but larger than what happened in many other countries and regions. It is particularly visible that some countries and regions, namely Singapore, Macao, Japan, Taiwan, and Korea scored significantly higher than all other countries/economies in mathematics (575 to 536 points), and outperformed all other countries and economies. Overall, these South East Asian countries were able to sustain or even increase their 15-year-olds math literacy (see Figure 1). Another 17 countries also performed above the current OECD average (472 points), ranging from Estonia (510 points) to New Zealand (479 points). Equally striking is that Finland, which was considered by some educational currents to be a model country,

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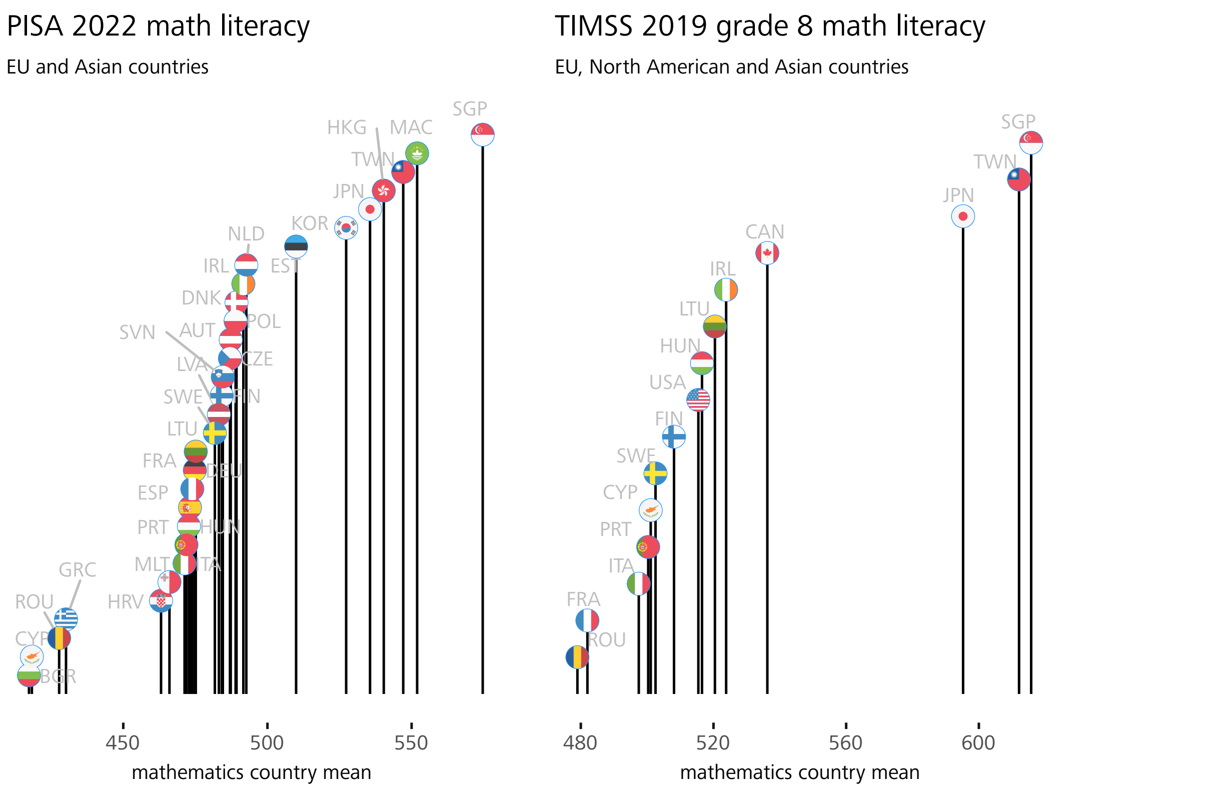
[1] This short article incorporates parts of a short report the first author wrote for the EMS Executive Committee shortly after PISA 2022 results were released on 5 December 2023. The note benefitted from some comments and suggestions from the EMS Education Committee. In any circumstance, the two authors assume fully responsibility for the statements and views here expressed.

Jurisdiction	2003	2006	2009	2012	2015	2018	2022	*Progression*	Change 2022–2018	Change 2022–2003
International Average (OECD)	499	490	492	488	485	487	472		−15	−27
Austria (AUT)	506	505	496	506	497	499	487		−12	−19
Belgium (BEL)	529	520	515	515	507	508	489		−19	−40
Canada (CAN)	532	527	527	518	516	512	497		−15	−35
Czech Republic (CZE)	516	510	493	499	492	499	487		−12	−29
Denmark (DNK)	514	513	503	500	511	509	489		−20	−25
Estonia (EST)		515	512	521	520	523	510		−13	−5
Finland (FIN)	544	548	541	519	511	507	484		−23	−60
France (FRA)	511	496	497	495	493	495	474		−21	−37
Germany (DEU)	503	504	513	514	506	500	475		−25	−28
Greece (GRC)	445	459	466	453	454	451	430		−21	−15
Hungary (HUN)	490	491	490	477	477	481	473		−8	−17
Ireland (IRL)	503	501	487	501	504	500	492		−8	−11
Italy (ITA)	466	462	483	485	490	487	471		−16	5
Japan (JPN)	534	523	529	536	532	527	536		9	2
Korea (KOR)	542	547	546	554	524	526	527		1	−15
Latvia (LVA)	483	486	482	491	482	496	483		−13	0
Lithuania (LTU)		486	477	479	478	481	475		−6	−11
Luxembourg (LUX)	493	490	489	490	486	483				−10
Netherlands (NLD)	538	531	526	523	512	519	493		−26	−45
Poland (POL)	490	495	495	518	504	516	489		−27	−1
Portugal (PRT)	466	466	487	487	492	492	472		−20	6
Slovenia (SVN)		504	501	501	510	509	485		−24	−19
Spain (ESP)	485	480	483	484	486	481	473		−8	−12
Sweden (SWE)	509	502	494	478	494	502	482		−20	−27
United States (USA)	483	474	487	481	470	478	465		−13	−18
Bulgaria (BGR)		413	428	439	441	436	417		−19	4
Chinese Taipei (TWN)		549	543	560	542	531	547		16	−2
Croatia (HRV)		467	460	471	464	464	463		−1	−4
Cyprus (CYP)				440	437	451	418		−33	−22
Hong Kong (China) (HKG)	550	547	555	561	548	551	540		−11	−10
Macao (China) (MAC)	527	525	525	538	544	558	552		−6	25
Malta (MLT)					479	472	466		−6	−13
Romania (ROU)		415	427	445	444	430	428		−2	13
Singapore (SGP)			562	573	564	569	575		6	13

Notes: 1. Average scores rounded to units; 2. Changes were computed for available data. If a jurisdiction does not have data for a given year, computations used the next available year's data.

Source: Organization for Economic Co-operation and Development (OECD): https://doi.org/10.1787/19963777

Table 1. Evolution of mathematics literacy in European, North American, and South East Asian selected jurisdictions. Data from OECD (2021–2023).



(a) (b)

Figure 1. PISA 2022 (a) and TIMSS 2019 (b) mathematics literacy scores in selected European, North American and Asian countries (see Table 1 for country names). The vertical axis is the rank of the countries adjusted for the figure height. Canada's value in TIMSS is the average of the Ontario and Quebec provinces.

continued its decline, initiated in 2006. Finland scored 484 points, below Slovenia and the Czech Republic, for instance. In Europe, Estonia (510) is maintaining its place above all other European countries. It is now clearly established that the pandemic took a toll on European mathematics learning, contradicting some optimistic early assessments. But the pandemic does not explain everything. Comparing countries with the same number of lockdown days, we notice that many European countries show regresses that are not solely explained by the pandemic.[2]

It is also of direct interest for mathematics education to look at TIMSS results, in particular at the TIMSS results for 8th graders in mathematics. These TIMSS country results are highly correlated to the PISA ones. It is thus not surprising that most European countries are not performing well and that Singapore, Taiwan, Japan are far ahead of European countries. Figure 1 (b) illustrates the gap between countries in South East Asia and Europe for math literacy, measured in TIMSS 2019.

[2] OECD, PISA 2022 Database, Tables I.B1.2.1, I.B1.2.2, I.B1.2.3, I.B1.4.42, I.B1.4.43, I.B1.5.4, I.B1.5.5 and I.B1.5.6 [7, pp. 29–30].

It is also now clearly established that the learning losses in European countries are not a minor and temporary issue. Year after year, for longer than a decade, the decline is consistently shown in PISA and TIMSS surveys and should be seriously tackled (see Figure 2).

Long-term trends

Decline in PISA results in mathematics have been almost constant for European countries along the last decade. Decline from 2018 to 2022 happened in all European countries, with an average drop of 18.8 points (see Table 1 and Figure 2). For reference, it is usually considered that a decline of 20 to 30 points corresponds to a loss of a school year instruction. We can also estimate, for instance, that Singaporean students, who are scoring 575 points, are about three to almost four school years cognitively ahead of European students, who scored on average 480 points. This difference in not inevitable, as the decline of student results is not inevitable. Some countries such as Singapore, Taiwan, and others are showing a steady long-term improvement. These global results represent

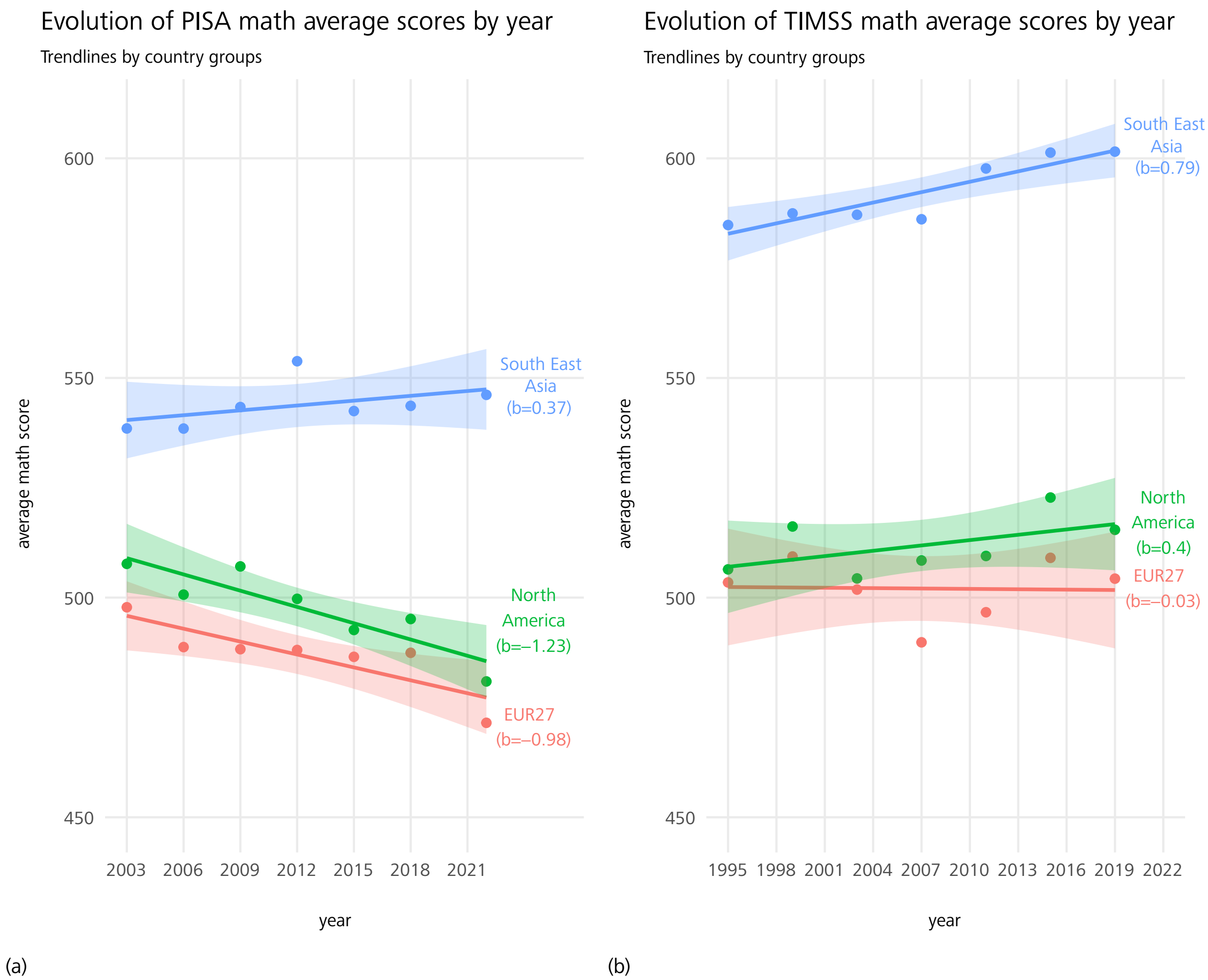


Figure 2. Trends for PISA (a) and TIMSS (b) mathematics literacy in selected European, North American and South East Asian jurisdictions (see Table 1 for the list of countries used in each block). The "b" coefficient is the linear slope of the lines (score points/year). Colour bands and the 95% confidence intervals for the regression lines are shown, calculated from OECD and IEA data.

a serious warning to European education, science, competitiveness, and mathematical research.

More recently, OECD released the results for the fourth domain surveyed in this PISA wave: Creativity. The results are also important for mathematicians. It is many times said that South East Asian countries are ahead in school mathematics because they concentrate on rote fact memorisation and rote procedural practices. They would lack creativity, which is a major drive for technological innovation and economic competitiveness. Results for the creativity category are very interesting in this regard. Singapore is ahead of all other countries, both in school mathematics and in creativity as measured by PISA. Other Asian countries are also ahead in both categories. Furthermore, data show a significant correlation between countries' results in these two areas. Figure 3, retrieved from OECD publications, is very illuminating.

Why should mathematicians be worried

There are several reasons why we should be worried by these results. Primarily, there are issues concerning the opportunities provided for future generations. No one should be satisfied when their nation's youth is not having the best education possible. We, as European citizens, should be worried about our youth's future. Secondly, there are economic and social issues. We now know from several statistical and econometric research projects that human capital formation, as measured by PISA and other standardised measures, has a decisive impact on the economic foundations and development of countries. See, e.g., [4] for a thorough review. Thirdly, there is one seemingly egotistic reason. As professors and researchers, a suboptimal mathematics education means suboptimal and harsh class teaching, fewer talented students, fewer graduate students, and less productive research [3]. Although one can dismiss these concerns saying what matters for professional mathematics

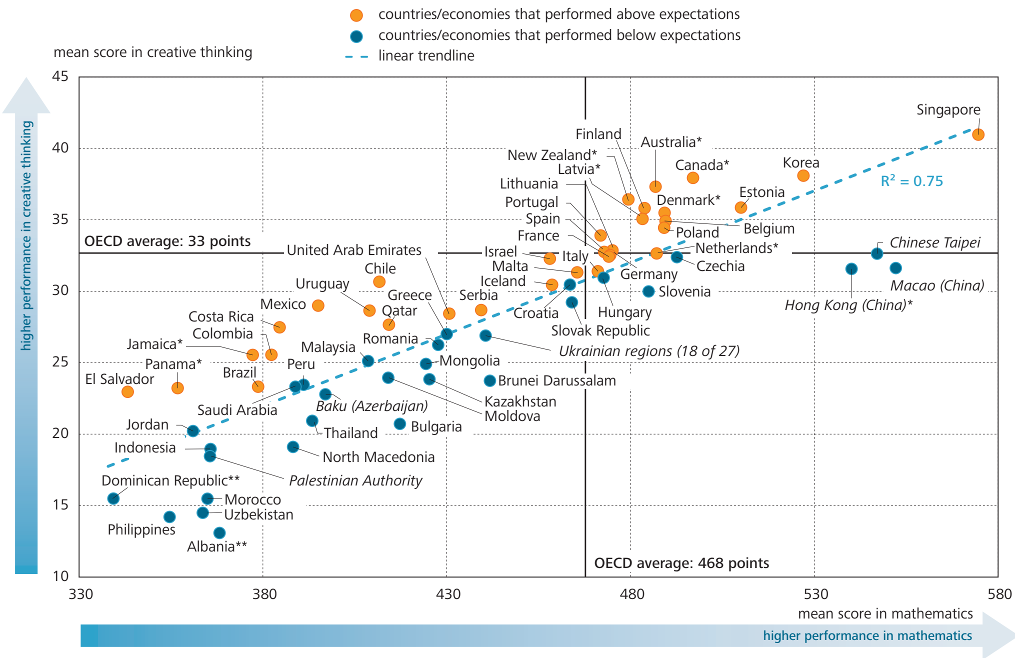


Figure 3. Mean creative thinking and mathematics performance. OECD Notes: Only the 64 countries and economies that implemented the creative thinking cognitive test are shown. A student's relative performance in creative thinking is defined as the residual obtained upon a cubic polynomial regression of the student's performance in creative thinking over his or her performance in mathematics or reading. The regression is performed at an international level, pooling data from all countries and economies that participated in the creative thinking assessment. Source: OECD, PISA 2022 Database, Tables III.B1.2.1. and III.B1.2.4.[3]

is simply a small pool of good minds, this pool becomes smaller and smaller in Europe as worse results on country averages reduce the availability of high achievers. None of these motives, though, is actually egotistic. Decades of research have highlighted the importance of both success in basic skills and success in preparing talented people, as one factor reinforces the other and both contribute to economic and social development. As Hanushek and Woessmann summarise in [4, p. 64], "achieving basic literacy for all may well be a precondition for identifying those who can reach 'rocket scientist' status" and "a large pool of those with basic skills may be an efficient way to obtain a large share of high performers."

Overall, the decline in math literacy among European students poses a significant threat to scientific progress, economic development, educational quality, societal well-being, and the future of research and academia in Europe. Addressing this issue is crucial for sustaining innovation, competitiveness, and a well-informed and capable society.

And now, what?

The problems with mathematics education in Europe have been known for quite some time, and PISA and TIMSS surveys are constantly showing red flags about our performance. To improve the situation, there are a couple of fundamental basic steps already, proven to work elsewhere [1, 5] and that can be recommended after the last PISA wave [2]:

- Follow the modern scientific evidence about focused, progressive and coherent curriculum, direct instruction methods and student evaluation.
- Promote more rigorous and demanding stable curricula, better structured and sequentially coherent, and significant.
- Increase student awareness of mathematical knowledge importance and applicability.
- Pay special attention to equity in education, not only equity between genders, but also work against the fact that socioeconomic and other circumstances still hinder the education achievement of disadvantaged students.
- Follow with special attention students that are staying behind and provide them content knowledge tutoring, instead of lowering curricular standards.
- Equally follow with special attention students that are in the highest performing levels and provide them with opportunities for further deepening their knowledge.
- Better evaluate the status of mathematics education in our countries through high-stakes and low-stakes frequent and rigorous student assessments.

[3] https://stat.link/o12ktl

- Press for a more complete and rigorous initial teacher training in mathematics, stressing the need for the topics they will need to teach at the elementary and secondary school levels.

References

[1] N. Crato, Curriculum and educational reforms in Portugal: An analysis on why and how students' knowledge and skills improved. In: *Audacious Education Purposes*, pp. 209–231, Springer, Cham (2020)

[2] N. Crato (ed.), Improving a country's education: PISA 2018 results in 10 countries. Springer, Cham (2021)

[3] N. Crato, Math curriculum matters: Statistical evidence and the Portuguese experience. *Eur. Math. Soc. Mag.* **124**, 49–56 (2022)

[4] E. A. Hanushek and L. Woessmann, *The knowledge capital of nations: Education and economics of growth*. The MIT Press, London (2015)

[5] J. Marôco, Portugal: The PISA effects on education. In *Improving a Country's Education* [2], pp. 159–174, Springer, Cham (2021)

[6] OECD, PISA. (2000–2024)

[7] OECD, PISA 2022 Results (Volume I). (2023)

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Celebrating four decades of the Centre de Recerca Matemàtica

Pau Varela

Frontal view of the CRM building, located in the UAB Campus in Bellaterra. (© Centre de Recerca Matemàtica)

Celebration of the CRM 40th anniversary at IEC. From left to right: Prof. Manuel Castellet (founder and first director of the CRM), Mr. Joaquim Nin, Secretary General of Research and Universities of the Government of Catalonia, Ms. Teresa Cabré, president of the Institute of Catalan Studies, Prof. Lluís Alsedà, director of the CRM, and Prof. Joaquim Bruna, former director of the CRM. (© Centre de Recerca Matemàtica)

Founded in 1984, the Centre de Recerca Matemàtica (CRM) has significantly advanced mathematical research in Catalonia, receiving prestigious awards and international recognition.

Created by the Institut d'Estudis Catalans, the CRM promotes international collaboration and advanced training, hosting events and supporting research in both fundamental and applied mathematics to address societal challenges.

On 9 May, the Centre de Recerca Matemàtica (CRM) celebrated its 40th anniversary with a special event at the Institut d'Estudis Catalans (IEC). The celebration featured a lecture by Madhu Sudan, a renowned mathematician and computer scientist from Harvard University, and included speeches by the Secretary General of Research and Universities of the Generalitat de Catalunya, the president of the IEC, and the three directors who have led the centre since its inception. This occasion provided an opportunity to reflect on the history and evolution of the CRM, highlighting the significant milestones and changes the centre has experienced over the past four decades.

Since the CRM opened its doors in 1984, at the initiative of Manuel Castellet, a professor at the Universitat Autònoma de Barcelona (UAB), the centre's goal has been to increase research capacity and the level of mathematical research in Catalonia, promote its dissemination, and act as a catalyst for collaboration with renowned international mathematicians. Today, the CRM operates as a consortium between the Generalitat de Catalunya, the IEC, and the UAB. It is the oldest centre in the CERCA network of research institutes supported by the Catalan government and is a member of the European Research Centres on Mathematics (ERCOM).

In these four decades of existence, the CRM has received several recognitions, such as the Narcís Monturiol Award for Scientific and Technological Merit and the María de Maeztu Unit of Excellence award, a distinction that recognizes national research institutions with highly competitive strategic programs, which the CRM has received twice.

A hub for the mathematical community

In Catalonia, prior to the establishment of the CRM, mathematical research was primarily conducted within academic settings and led

EMS MAGAZINE 133 (2024) — DOI 10.4171/MAG/211

by university professors. By the late 1970s and early 1980s, notable advancements were made in the research conditions within university mathematics departments. During this period, there was a surge in researchers' aspirations to publish in international journals, an increase in visits from prominent figures, and a rise in the production of high-quality doctoral theses.

Recognizing this significant growth in mathematical research, the need for a dedicated research institute became evident. This led to the establishment of the CRM, marking a significant milestone as the first research institution in Spain devoted exclusively to mathematics. Over the past four decades, the CRM has been instrumental in strengthening and expanding mathematical research in the region. Its creation facilitated the collaboration among various Catalan university departments, fostering a dynamic environment for innovation and discovery.

The CRM organizes a diverse array of scientific events each year, including advanced courses, conferences, workshops, and seminars. These events feature invited speakers from around the globe, ensuring a rich exchange of knowledge and expertise. (© Centre de Recerca Matemàtica)

Since its early days, the Centre de Recerca Matemàtica (CRM) has dedicated its facilities to encourage cooperation within the mathematical community. Mathematics is uniquely reliant on the human factor, with progress often driven by interaction and collaboration among researchers worldwide. To support this, the CRM has designed its spaces to promote the exchange of knowledge and ideas. The centre's infrastructure encourages a positive space for productive discussions, enabling researchers from around the globe to effectively share insights and advance mathematical research together.

Situated in the Faculty of Sciences and Biosciences at the Universitat Autònoma de Barcelona (UAB), the CRM is well equipped to host premier events such as conferences, seminars, and congresses. Each year, the centre welcomes over a hundred mathematicians and researchers from other disciplines from across the world, who come as invited speakers, participants in scientific activities, or through funding programs like the Lluís Santaló Scholarship and the Research in Pairs program, which support long-term stays.

Training the next generation of mathematicians

In addition to serving as a hub for international collaboration, the CRM is deeply committed to nurturing young researchers and promoting diverse perspectives in mathematical research. The first PhD fellowships at the CRM were granted in 1988, highlighting the centre's dedication to providing equal opportunities for advanced training in mathematics and bringing up the next generation of mathematical talent.

The CRM took a significant step towards its current stature as a leading research institution in 2008 by developing its own research structure. This structure now comprises eight groups that cover a wide spectrum of mathematical disciplines, from fundamental mathematics to various applied fields. By bridging the gap between pure and applied mathematics and addressing real-world phenomena through advanced mathematical frameworks, the CRM not only advances mathematical theory but also tackles practical challenges across numerous scientific and societal domains. This integrative approach ensures that the CRM remains at the forefront of both theoretical and applied mathematical research.

The CRM spaces are thoughtfully designed to foster discussion and exchanges among both senior researchers and invited speakers, as well as younger researchers. (© Centre de Recerca Matemàtica)

In recent years, the CRM's research structure has been further strengthened with an influx of new talent, consolidating and integrating its research groups, which now include researchers from the Universitat Autònoma de Barcelona (UAB), the Universitat de

Barcelona (UB), and the Universitat Politècnica de Catalunya (UPC), alongside the CRM's own research staff. Both UB and UPC are also in the process of joining the CRM's board of trustees.

Currently, the CRM has 126 affiliated researchers, including established scholars, postdoctoral researchers, and doctoral students, all contributing to a vibrant and diverse research community. This collective expertise creates a rich and collaborative atmosphere, encouraging the exploration of mathematical research from all diverse perspectives.

The CRM auditorium is one of four available rooms for hosting events. Each room is fully equipped to facilitate online or hybrid format meetings, ensuring flexibility and accessibility for all participants.
(© Centre de Recerca Matemàtica)

Much accomplished, much to do

As the Centre de Recerca Matemàtica (CRM) celebrates its 40th anniversary, it reaffirms its mission to hold a standard of excellence in mathematical research and training on an international scale. Over the past four decades, the CRM has focused on conducting high-quality research, with an emphasis on real-world applications in collaborative and interdisciplinary contexts. This mission includes the transfer of knowledge derived from mathematical research, paying special attention to the implementation of models that address emerging social issues.

This milestone is a chance to reflect on our journey so far, while we prepare to tackle the challenges that lie ahead. Through sustained excellence in research and the promotion of collaboration, the CRM aims to shape the future of mathematics worldwide.

Research at CRM is conducted in an open environment that actively encourages collaboration among various research groups.
(© Centre de Recerca Matemàtica)

How can I participate?

There are several ways to engage with the Centre de Recerca Matemàtica (CRM). One option is to organize a congress or scientific event at the CRM by applying through the scientific programs and events application process.[1] This allows researchers to utilize CRM's facilities and support and collaborate with international experts.

Additionally, the CRM offers funding opportunities for researchers to conduct research stays and collaborate with local mathematicians. These funding programs enable extended stays at the CRM, fostering deep collaboration and innovative research. You can find more detailed information on the CRM's portal for visitors.[2]

To stay updated on the latest news, opportunities and activities at CRM, consider signing up for our mailing list.[3]

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[1] https://www.crm.cat/scientific-programmes-events
[2] https://www.crm.cat/calls-for-visitors
[3] https://mailchi.mp/e0cf527a6773/crm-events

The GAMM Juniors

EMYA column regularly presented by Vesna Iršič

Andreas Warkentin, Richard Schussnig, Giuseppe Capobianco and Georgia Kikis

The group of GAMM Juniors consists of early-career scientists who represent the younger generation within the Association of Applied Mathematics and Mechanics (GAMM). This article provides an overview of the organization and activities of the GAMM Juniors. In particular, we share experiences, report on recent developments, and highlight potential opportunities.

1 Who are the GAMM Juniors?

GAMM Juniors[1] are young academics and members of the Association of Applied Mathematics and Mechanics (GAMM).[2] The GAMM, founded by Ludwig Prandtl and Richard von Mises in 1922, is an interdisciplinary network for researchers in applied mathematics and mechanics and their related fields.

Each year, about ten early-career scientists are appointed for three years by the GAMM Juniors selection committee. Hence, the GAMM Juniors are a group of currently 31 selected young researchers in applied mathematics and mechanics, see Figure 1. The first Juniors were nominated for the period 2012–2015. The appointment as a Junior is a recognition of scientific achievements and includes free membership in GAMM for the tenure period, as well as the opportunity to engage in the Juniors' activities.

The Juniors are self-organized and manage a broad spectrum of activities that target the personal and scientific development of young academics, see Section 3. Moreover, every year, the GAMM Juniors elect a speaker team consisting of a speaker, a deputy and a second deputy. The speaker participates in GAMM board meetings, represents the voice of young scientists within GAMM and has further responsibilities within the GAMM.

2 How to become a GAMM Junior?

Typically, each university's local GAMM representative nominates a maximum of two candidates for the Juniors to the GAMM office by 15 June every year. Since 2024, self-nomination is also possible. The nomination consists of a curriculum vitae and a recommendation of at most two pages each. Out of all nominations, the GAMM Juniors selection committee finally appoints ten candidates.

GAMM Juniors have graduated with exceptional achievements in their final thesis and/or PhD thesis in applied mathematics or mechanics within the last two years of the call and are younger than 32 years on that date. Deviations from this time frame due to inactive periods caused by sickness or maternity leaves are considered.

3 Activities

The GAMM Juniors organize themselves and meet twice a year in person to advance joint projects, network, and exchange scientific ideas. Over the past years, they have developed various projects and events related to the annual meeting and the personal growth of the Juniors.

3.1 Summer School on Applied Mathematics and Mechanics

Each year, the GAMM Juniors organize a Summer School on Applied Mathematics and Mechanics (SAMM), dedicated to a special topic in the field, focusing on current research questions. During the event, participants are introduced to the latest developments in areas of interest to GAMM. The 1st GAMM Juniors Summer School took place in 2014 and was on "Differential-Algebraic Equations – Theory and Control." Since then, various thematic fields have been covered, including *scientific machine learning, shape and topology optimization* and *materials with discontinuities*. The summer school has attracted young researchers beyond Germany, including Austria, France, the United Kingdom, and the Czech Republic, reaching up to 70 participants. This year's summer school (SAMM 2024)[3] on "Uncertainty Quantification, Stochastic Partial

[1] https://www.gamm-juniors.de

[2] https://www.gamm.org

[3] https://www.gamm-juniors.de/samm-2024

Figure 1. GAMM Juniors executive board (first row): A. Warketin (president), G. Capobianco (vice-president), G. Kikis (secretary); and members (ordered by year of nomination and alphabet): E. Eggenweiler, E. Herberg, P. Kinon, L. Lanza, M. Merkel, A. Othmane, A. Pešić, M. Pető, M. Reichel, R. Schussnig, P. Vieweg, J.-H. Bastek, N. Beranek, J. Berberich, M. Blaszczyk, H. Geisler, A. Henkes, V. von Oertzen, O. Weiß, C. Böhm, F. Castelli, L. Gesenhues, K. Klioba, S. Lanthaner, N. Reiter, I. Kulchytska-Ruchka, M. Schmidtchen, C. Witt.

Differential Equations and Risk Analysis" took place at ETH Zürich from 29 July to 1 August 2024.

Being part of the summer school's organizing team offers young researchers invaluable experience, as it allows them to independently conceptualize a scientific meeting, invite speakers, and develop the program. This format is crucial for learning about cutting-edge research topics, setting impulses, fostering the exchange of ideas, networking among participants, and promoting interdisciplinary communication. For instance, in 2021, a special issue [1] of PAMM (Proceedings in Applied Mathematics and Mechanics) was published for the first time following SAMM, featuring a collection of posters and proceedings edited by the SAMM organization team.

3.2 Accompanying events at the GAMM annual meeting

The GAMM Juniors are organizing a number of activities as part of the GAMM annual meeting. The *Pre-GAMM*[4] features a scientific segment and a soft-skill course. The scientific segment serves as an onboarding event with introductory lectures held the week before the annual meeting, preparing attendees for the plenary talks. The *soft-skill session* targets young researchers attending a conference for the first time. Held in the morning before the conference opening, it allows participants to seek advice from experienced experts on topics such as presentation tips, initiating conversations, and creating a personal conference agenda. A particularly well-received format is the *YAMM Lunch*[5] – an open

[4] https://www.gamm-juniors.de/activities/pre-gamm

[5] https://www.gamm-juniors.de/activities/yamm-lunch

discussion during lunch where young researchers can get in touch with the community's established experts on career planning, work-life balance, networking and more. A *poster session* is organized featuring current GAMM Juniors to present their research, enhancing their visibility and facilitating discussions with other conference participants.

3.3 The journal GAMMAS

To enhance the visibility of early career scientific contributions, the GAMM Juniors established the online journal GAMMAS[6] (GAMM Archive for Students) in 2018. This platform allows young peers to submit articles, including selected aspects of seminars or theses, providing an early opportunity to publish their initial works and gain insight into the publishing process. The journal is divided into three main categories: *research articles, technical briefs,* and *educational articles*.

Research articles and technical briefs are authored by students until one year after graduation (MSc), while educational articles can be authored by students as well as graduated researchers. Submissions in these categories can include detailed experiment descriptions, comprehensive proofs, illustrative negative examples, development and/or experimental validation of models, development of novel analytic or numerical methods, introduction of novel experimental techniques, combination and/or comparison of existing methods, providing introductions to modern topics not yet covered by standard textbooks, and reporting negative results.

The journal is managed entirely by the GAMM Juniors, with the speaker team serving as the editorial board. Each year, GAMM awards the best paper published in GAMMAS, offering a prize of 300 euros, designated for attendance at a scientific event or a research visit. We encourage you to seize this opportunity and motivate your students to submit their contributions to GAMMAS. Guidelines are given on the journal website.[6]

3.4 Mailing list 'young-academics-in-gamm'

The GAMM Juniors established the mailing list *young-academics-in-gamm*[7] to share information with and from young researchers, including summer schools, workshops, job offers, and GAMM Juniors activities from all over the world. The mailing list is open to all, allowing subscribers to distribute announcements and offers.

3.5 Mentoring program

The Mentoring Program is designed to support the personal and academic growth of the GAMM Juniors through informal exchanges with established members of the GAMM community. The program features one year of one-on-one mentoring, where mentees receive personalized guidance from experienced mentors. This allows established scientists to share their knowledge and insights with the next generation. Mentees benefit from tailored advice on various academic and scientific topics, such as networking, writing grant proposals, work-life balance, scientific outreach, and finding positions in academia. Looking ahead, we aim to expand this program to make it accessible to all early-stage researchers within GAMM, thereby enhancing the support network and fostering the development of young scientists.

3.6 Science communication

The goal of this project is to dismantle stereotypes among students from diverse backgrounds and spark their interest in the exciting fields of mechanics and mathematics. Through targeted communication and educational initiatives, we strive to build a bridge to future generations, collaborating towards a more sustainable and technologically advanced future. Engineering and mathematics, in particular, play a crucial role in achieving a sustainable future, and we are committed to highlighting their importance and potential.

3.7 Knowledge Briefs

Knowledge Briefs are monthly 30-minute online presentations designed to make complex topics understandable for everyone, regardless of their field. Active Juniors select the topics, which are then presented by experts. A subsequent 30-minute Q&A session deepens understanding. Although topics are chosen by current Juniors, the presentations are open to all interested parties, including alumni, who can also submit their topics for selection. The goal is to make knowledge accessible, promote interdisciplinary learning, and strengthen the exchange between current and former members, continuously expanding the knowledge base. For further information, join our Discord channel (see Table 1).

3.8 Fall meeting

The Juniors convene every autumn to thoroughly discuss the current status of ongoing and new projects, as well as to launch new initiatives, and to strengthen social bonds. Additionally, a session dedicated to interdisciplinary scientific talks is scheduled each year to initiate and intensify research collaborations. Most recently, the board of GAMM and the GAMM Juniors took the opportunity of the fall meeting 2023 to directly exchange ideas and discuss current topics within the organization, as well as the development of the Juniors themselves. Newly elected Juniors are integrated into the projects based on their personal preferences, enabling them to actively participate in the projects of their choice. Joint recreational activities round off the fall meetings.

[6] https://www.bibliothek.tu-chemnitz.de/ojs/index.php/GAMMAS
[7] https://mailman.zih.tu-dresden.de/groups/listinfo/young-academics-in-gamm

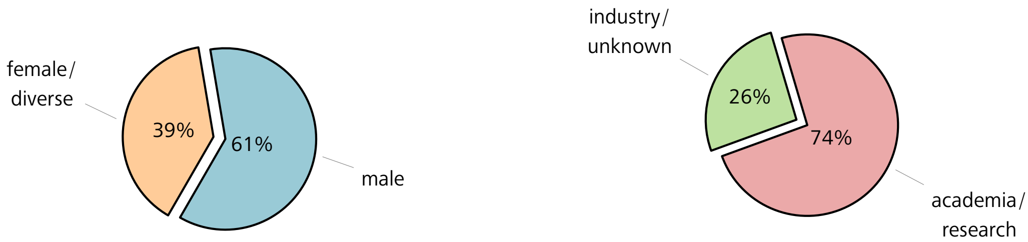

Figure 2. GAMM Juniors and alumni statistics: sex distribution and profession of the alumni.

4 Network and impact of the GAMM Juniors

The GAMM Juniors consider themselves as the connecting link between GAMM and the community of young scientists from mathematics and mechanics in Central Europe, and as one of the main driving forces for innovation within the association. The GAMM Juniors develop new ideas and concepts for the benefit of the community and beyond, bring ideas and visions to life to improve the status quo, and promote, motivate, and connect young researchers. The first two of these core missions are realized through the projects of the GAMM Juniors described in the previous section, while the long-term impact within the community is less apparent and therefore more difficult to describe and measure. The GAMM Juniors offer opportunities to engage within the young researcher community with close contact to alumni, forming a dense network of professionals in academia and industry, 61% of whom are male, while 39% are female/diverse. The percentage of Juniors alumni in academia or at research institutes is 74%, while 26% have moved to industry (see Figure 2).

Joining the GAMM Juniors connects you with a dedicated community of young, motivated scientists in the early stages of their careers. Engaging with other GAMM Juniors facilitates discussions about scientific ideas beyond one's own field of expertise, sharing experiences regarding PhD or postdoc positions, initiating collaborative projects, and building a sustainable network based on mutual support. This fosters interdisciplinary collaborations, such as the joint organization of minisymposia at conferences. Additionally, the projects organized by GAMM Juniors, including the Mentoring Program and the YAMM lunch, offer valuable opportunities to engage with experienced researchers in our community. Being a GAMM Junior also enhances your visibility in the scientific world. Several former GAMM Juniors have achieved notable success in academia, now serving as professors in their respective fields, such as Prof. Dr. Claudia Schillings from the Free University of Berlin and Prof. Dr.-Ing. Merten Stender from TU Berlin.

In conclusion, we believe that the GAMM Juniors provide great ways to engage with young members within the community of mathematics and mechanics. They offer a platform to exchange scientific and non-scientific ideas, making them a key driver of innovation within the GAMM. On behalf of all Juniors, we thank the GAMM for this fantastic opportunity and for the support and trust placed in our projects!

Would you like to meet other young researchers and get familiar with cutting-edge methods in current research before the next GAMM annual meeting? – We look forward to welcoming you at the next Pre-GAMM! Or directly get in touch via juniors@gamm.org

"The network I cultivated during my time as a GAMM Junior has proven invaluable, providing me with enduring connections that extend beyond research fields and university affiliations. These relationships continue to enrich my professional endeavors, offering ongoing support and collaboration opportunities."

Prof. Dr.
Claudia Schillings
Freie Universität Berlin
GAMM Junior
2014–2016

Photo: © Kay Henschel

"The time as GAMM Junior has been instrumental in shaping my scientific career by providing invaluable mentorship, networking opportunities, and access to cutting-edge research. This collaborative environment has significantly enhanced my skills and provided the key confidence to pursue a career in academia."

Prof. Dr.-Ing.
Merten Stender
TU Berlin
GAMM Junior
2020–2023

Photo: © Christian Kielmann

(a)	(b)	(c)	(d)	(e)

Table 1. Get in contact with the Juniors: visit our website (a), check out GAMMAS (b), join our discord server (c), visit and follow our LinkedIn account (d) and pay the SAMM homepage (e) a visit!

or join our discord server,[8] where we keep you informed and up to date with various developments within our community, providing a space for continuous learning and engagement. Also make sure to visit our pages,[9] see the QR codes in Table 1.

References

[1] 7th GAMM Juniors' Summer School on Applied Mathematics and Mechanics (SAMM20). *PAMM* **20**, article no. e202000901 (2021)

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[8] https://discord.gg/X69uV5xQ67

[9] https://www.gamm-juniors.de,
GAMMAS: https://www.bibliothek.tu-chemnitz.de/ojs/index.php/gammas,
SAMM: https://www.gamm-juniors.de/samm-2024

Memorabilia from past ICMs recently acquired by the IMU Archive

This article follows on from the article on the IMU/ICMI Archive by Birgit Seeliger and Bernard R. Hodgson published in [8].

June Barrow-Green

Bologna 1928

In June 2023 I had the pleasure of visiting the IMU Archive and spending time with the archivist, Birgit Seeliger, who guided me around. One of the highlights of my visit was the arrival of a lapel pin made for the 1928 Bologna International Congress of Mathematicians (ICM). It had been donated to the archive by Melanie Zwick who had found it amongst her late grandmother's possessions. Since Ms. Zwick had no idea how her grandmother had acquired the pin and was not aware of any mathematicians in the family, she also provided a family tree in case anyone at the Archive could identify a mathematician in it. However, despite scouring the Bologna ICM Proceedings[1] and extensive googling, we drew a blank. Perhaps the pin was a gift to her grandmother from someone outside the family or perhaps her grandmother had found it in a flea market!

Pin from the 1928 Bologna ICM.

The medal was designed by the Bolognese sculptor and medallist Alfonso Borghesani (several of whose works are in university buildings in Bologna). The obverse shows the seated figure of Libertas – the name is inscribed on her shield – with a lion at her feet, symbolising the city of Bologna (both Libertas and a lion feature on the city's coat of arms). To the left is a tower representing one of the city's famous Two Towers. The reverse is inscribed:

CONGRESSO
INTERNAZIONALE
DEI MATEMATICI
BOLOGNA MCMXXVIII
ANNO VI

The "ANNO VI" (which also appears in the congress proceedings as "(VI)"), refers to year 6 of the Era Fascista (not, as is sometimes assumed, to the number of the congress). Originally 1100 medals were cast, but due to the increase in the number of participants during the congress, a further 300 had to be ordered. This information is revealed in an article on the congress in the *Bollettino di Matematica* in which an image of the pin is also reproduced [1, p. 158]. I am grateful to Erika Luciano of the University of Turin for drawing this article to my attention.

Bologna was not the only ICM to hand out something for delegates to wear on their lapels. Whether anything similar had been created for an ICM before Bologna is not known, but lapel badges certainly featured in the ICM in Oslo in 1936. An attendee at the congress, G. Waldo Dunnington, an American professor of German known for his writings on Gauss, reported that: "Delegates to the congress wore a badge in the form of an integral sign, which entitled them to ride free on the street cars and busses [sic] in Oslo and vicinity" [3]. It seems that the organizers had chosen the integral sign as a logo for the congress since it also appears on the title page of the proceedings.[1] No example of the Oslo badge has yet come to light, but it lives on in the title of the recent book on the Oslo congress by Christopher Hollings and Reinhard Siegmund-Schultze who take their title from Dunnington's article [4].

Amsterdam 1954

In November 2023, Birgit contacted me to let me know that the Archive had recently received a gift of documents relating to the Amsterdam ICM of 1954. This was particularly welcome as the Archive has very little memorabilia relating to this congress.

[1] ICM Proceedings 1893–2022 can be found online at https://www.mathunion.org/icm/proceedings.

EMS MAGAZINE 133 (2024) — DOI 10.4171/MAG/203

Poster and pendant from the 1954 Amsterdam ICM.

The donation came from the daughter of the mathematician R. M. Th. E. Oomes (1926–2010). Oomes is listed in the congress proceedings[1] as an "assistant," and he appears in the list of volunteers (which forms part of the donation), as one of those coming from Leiden. He later became a mathematics teacher at a Catholic high school in Leiden (now Bonaventura College). Little else is known about him apart from the fact that in the year 2000 his name appears as a co-author of an article about the tombstone of the German–Dutch mathematician Ludolph van Ceulen (1540–1610), who died in Leiden and who is famous for giving the constant π correct to 20 decimal places [6].

In common with many of my colleagues, the one thing I already knew about the Amsterdam ICM was that an exhibition of the work of the graphic artist M. C. Escher had been put on specially for participants at the congress, and that it was there that Sir Roger Penrose encountered Escher's work for the first time [5, 7]. Consequently, on hearing the news about the donation of Amsterdam ICM documents, I hoped that something about the Escher exhibition might be amongst them. Although there was nothing specific, the *Congress Guide*, a copy of which is part of the donation, contains the following description:

> *During the week of the Congress an exposition of graphical work by M. C. Escher will be held in the Stedelijk Museum, 13, Paulus Potterstraat.*
> *It is no wonder that especially mathematicians feel attracted by the work of Escher, which for a great deal is based on fascinating geometrical motives. Partially his work consists of symbolic-fantastic woodcuts in which the fundamental domains of regular plane-division are elaborated into artistic realizations. In addition, there are representations of special motives which attack the Euclidean character of the space in a witty and machinating way.*
> *Escher is a pupil of S. Jessurun de Mesquita. In his work the influence of the mosaics of the Alhambra in Granada may be perceived.*
> *Any artminded mathematician will enjoy a visit to the exposition in the Stedelijk Museum, which moreover deserves interest by the presence of an exclusive collection of modern paintings (after 1850, e.g., van Gogh).*

The guide is full of information about other extracurricular activities, including excursions to the Royal Blast Furnaces and Steelworks at Velsen, the North Sea Locks at Ijmuiden, and trips to Delft and The Hague. As well as several concerts, amongst the more sedentary activities on offer was the opportunity to watch "a simultaneous chess game" featuring Dr. M. Euwe, a former world champion who was described as the "finest example of the combination of mathematician and chess player." The guide also contains a welcoming speech from the (absent) Prince Bernhard, Prince Consort of the Netherlands, as well as an invitation to participants to purchase a tablecloth featuring "the Gaussian primes and woven after the indications of Prof. Balth. van der Pol," which apparently was still available for sale in 2009 [2, p. 137]. Perhaps not as many were sold as originally hoped!

On the scientific side, the donation includes Oomes' annotated copy of the *Scientific Congress*. This lists all the talks given at the congress, beginning with John von Neumann on "Unsolved problems in mathematics" and closing with Andrei Kolmogorov on "General theories of dynamical systems and classical mechanics." Oomes has crossed out several talks and inserted several new ones – presumably his own form of updating. Others that are marked are probably those he wanted to attend himself. Linked to his copy of the *Scientific Congress* is his annotated *Symposia Programme*. The three symposia – A. Stochastic Processes (Hon. President R. M. Frechet), B. Algebraic Geometry (Hon. President F. Severi), C. Mathematical Interpretation of Formal Systems (Hon. President E. Borel) – were run independently of, but in conjunction with, the congress, their lectures being published in the congress proceedings apart from those of C., which appeared in *Studies in Logic and the Foundations of Mathematics* (1955).

Other items in the donation include several administrative documents concerning the secretariat, lists of participants, maps of the congress venue, a menu of the congress banquet, and a catalogue from the local booksellers and publishers, Zwets & Zeitlinger, listing about 1400 mathematical books for sale. There are also two small terracotta pendants, approximately 5 cm long, in the form of the logo of the congress. Since these pendants have no chain or pin, it is not clear how they were meant to be worn or displayed.

One of the most interesting items in the donation is a photograph from the front page of the *Nieuwe Rotterdamse Courant* of 9 September 1954. This shows Queen Juliana of the Netherlands in the garden of the Soestdijk Palace having what is described as a "cosy chit-chat" with Marshall Stone, Jan Schouten, Francesco Severi, Enrico Bompiani, and Mary Cartwright. The involvement of the Queen (and her consort) in the congress was clearly a great publicity coup for the congress organizers! The photograph is

"Yesterday afternoon at Soestdijk Palace, Queen Juliana met with representatives of the mathematics congress, which is being held in Amsterdam. A cosy chit-chat in the garden: from left to right, Prof. J. A. Schouten, the Queen, Prof. M. H. Stone, Prof. F. Severi, Prof. N. E. Bompiani; seen on the back is Miss Cartwright."

reproduced in [2, p. 134], but without the names of the mathematicians. Note that the original caption (translated above) listed Stone and Schouten in incorrect order.

Acknowledgements. I am grateful to Jan van den Heuvel, my colleague at the London School of Economics, who provided me with information about Oomes and translated the caption to the photograph in the *Nieuwe Rotterdamse Courant*.

References

[1] A. Conti, Il Congresso Internazionale Matematico di Bologna. *Bollettino di Mat.* **XXIV**, 142–160 (1928)

[2] G. P. Curbera, *Mathematicians of the world, unite!* The International Congress of Mathematicians – A human endeavor. A. K. Peters, Wellesley, MA (2009)

[3] G. W. Dunnington, Oslo under the Integral Sign. *Natl. Math. Mag.* **11**, 85–94 (1936)

[4] C. D. Hollings and R. Siegmund-Schultze, *Meeting under the integral sign?* Hist. Math. 44, American Mathematical Society, Providence, RI (2020)

[5] E. Kersten, International Congress of Mathematicians 1954. https://www.escherinhetpaleis.nl/escher-today/international-congress-mathematicians-1954/?lang=en (2017), accessed 11 March 2024

[6] R. M. T. E. Oomes, J. J. T. M. Tersteeg and J. Top, The epitaph of Ludolph van Ceulen. *Nieuw Arch. Wiskd. (5)* **1**, 156–161 (2000)

[7] L. S. Penrose and R. Penrose, Impossible objects: a special type of visual illusion. *Br. J. Psychol.* **49**, 31–33 (1958)

[8] B. Seeliger and B. R. Hodgson, A resource supporting the development of mathematics: The IMU/ICMI Archive. *Eur. Math. Soc. Mag.* **133**, 62–65 (2024)

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Thematic Working Group on the Professional Practices, Preparation and Support of Mathematics Teacher Educators, TWG27

ERME column regularly presented by Frode Rønning and Andreas Stylianides

In this issue presented by the group leaders Ronnie Karsenty, Bettina Rösken-Winter, Stefan Zehetmeier, Birte Pöhler-Friedrich, Hilda Borko and Alf Coles

CERME Thematic Working Groups

We continue the initiative of introducing the CERME Thematic Working Groups, which we began in the September 2017 issue, focusing on ways in which European research in the field of mathematics education may be interesting or relevant for people working in pure and applied mathematics. Our aim is to disseminate developments in mathematics education research discussed at CERMEs and enrich the ERME community with new participants, who may benefit from hearing about research methods and findings and contribute to future CERMEs.

Introducing CERME Thematic Working Group 27: The Professional Practices, Preparation and Support of Mathematics Teacher Educators

Introduction

The role of Mathematics Teacher Educators (MTEs) is crucial in fostering mathematics teacher learning, during both the pre-service and the in-service periods of teachers' careers. At the in-service level, research has already shown that a critical precondition for the success of any professional development (PD) model at scale is the quality of the MTEs who facilitate the PD sessions [4, 5]. The role of these PD leaders is, on the one hand, to maintain integrity to the content goals and agenda of the PD program, yet, on the other hand, to be attentive to the characteristics and needs of the specific group of teachers and the idiosyncrasies of the given context [1]. Similarly, at the pre-service level, MTEs are expected to be adaptive and flexible in providing appropriate tasks around essential mathematics ideas, aimed at developing teacher knowledge, while tailoring their instruction to the particular characteristics and needs of the prospective teachers [2]. Whether they work at the in-service or the pre-service level, MTEs may have diverse backgrounds, for example, as mathematicians, mathematics teachers and mathematics education researchers. Each such background carries its own challenges for novice MTEs, even if they are experts in their original profession.

TWG27 is dedicated to current research concerning MTEs: their roles, their practices, the forms that their professionalization processes may take, the challenges they face, and more. The group started its activities at CERME12 (2022), recognizing the increasing interest in MTE research, as reflected in conferences (e.g., Educating the Educators[1]), books (e.g., [3]), journals and Special Issues focusing on the MTE profession. The establishment of TWG27 signified the importance ascribed to this topic as a separate body of research that stands on its own, rather than a subtopic of studying teacher learning, as was the case at CERME11 and earlier. TWG27 attracts a growing number of researchers who are active in advancing this emerging field, using multiple theoretical lenses and methodologies.

Topics at the core of TWG27

The following are the central topics that this group aims to forefront, each illustrated by representative questions or issues:

- Conceptualizing the role of MTEs (e.g.: What frameworks can be employed? How can theoretical or conceptual frameworks, used for researching mathematics teachers, be adapted to research MTEs?).
- Knowledge, beliefs, skills, identities and practices of MTEs (e.g.: What kind of mathematical knowledge is needed by different kinds of MTEs? How are generic and mathematical content-specific aspects integrated within the work of MTEs?).
- Learning mechanisms that may be useful for MTEs (e.g.: reflection, role-modeling, creating coherence between MTEs' own practices and the teaching practices they mean to support).
- Becoming MTEs – the preparation and support of novice MTEs (e.g.: Which tools and resources are effective along different stages in the MTE trajectory? What characterizes the transition process experienced by professionals such as mathematicians or teachers when they also assume the role of MTEs?).
- The influence of current global issues on the role and practices of MTEs (see below).

[1] https://educating-the-educators.icse.eu

Examples of issues discussed in TWG27 during CERME13

To portray the group's work at CERME13, we bring here two examples pertaining to the last two topics listed above, showing how these were interwoven and discussed across several contributions and contexts represented by various participants.

Resources for preparing and supporting MTEs

The contributions that focused on this issue illustrated the diversity of roles subsumed under the umbrella of MTEs and the different contexts in which these professionals work: facilitators of teacher PD, coaches working with individual teachers, and teacher educators working with prospective teachers. Despite this variety, similar arguments were offered for the importance of preparing and supporting MTEs, considering that MTEs' previous background and experiences are often not enough to ensure their readiness for their new role. The presented research employed different approaches, such as a formal Facilitator Professional Development (FPD) program offered to MTEs *before* they conduct their own PD, and a program offered to MTEs *in parallel* to their work with prospective teachers. All authors reported some positive impacts of the programs and identified topics for future research.

Challenges faced by MTEs in relation to global issues

A small but growing area of research into the roles and practices of MTEs concerns what MTEs do in relation to addressing questions of global challenges such as climate change. One framing that was presented centered on the use of *Environmental Socio-Scientific Issues* (EnvSSIs), i.e., issues involving some mathematical or scientific modeling, and reflection on the model and its implications for the living world. Common patterns of actions used in MTEs' work with undergraduates were discussed, for example, suggesting a mathematical problem relating to the EnvSSIs and working on it together, or asking prospective teachers to elicit ideas about implementing EnvSSIs in the classroom. Other findings presented showed that although a group of MTEs was unanimous about the importance of raising issues of climate change with prospective teachers, there were considerable differences in terms of the extent to which these MTEs enacted such beliefs.

Looking forward

Some of the issues identified as highly important for expanding our knowledge about MTEs are (a) moving beyond small-scale, qualitative studies to more generalizable, larger-scale studies; and (b) understanding how institutional capacity for teacher learning could be built, including what institutional factors may foster or hinder the effectiveness of teacher PD at scale. These, among others, continue to be a challenge for our community. We believe that the perspectives of mathematicians can contribute in this regard, as many mathematicians are involved in the design and implementation of programs for practicing as well as prospective mathematics teachers, where they either serve as MTEs themselves, or advise those leading the programs. As such, we wish to encourage all forms of involvement of mathematicians in this emerging research field.

References

[1] H. Borko, K. Koellner and J. Jacobs, Examining novice teacher leaders' facilitation of mathematics professional development. *J. Math. Behav.* **33**, 149-167 (2014)

[2] M. Goos, Investigating the professional learning and development of mathematics teacher educators: A theoretical discussion and research agenda. In *Crossing divides: Proceedings of the 32nd Annual Conference of the Mathematics Education Research Group of Australasia. Vol. 1*, pp. 209–216, MERGA, Palmerson North, New Zealand (2009)

[3] M. Goos and K. Beswick (eds), *The learning and development of mathematics teacher educators: International perspectives and challenges*. Springer, Cham (2021)

[4] B. Rösken-Winter, S. Schüler, R. Stahnke and S. Blömeke, Effective CPD on a large scale: Examining the development of multipliers. *ZDM Math. Educ.* **47**, 13–25 (2015)

[5] S. Zehetmeier, Sustaining and scaling up the impact of professional development programmes. *ZDM Math. Educ.* **47**, 117–128 (2015)

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A resource supporting the development of mathematics: The IMU/ICMI Archive

ICMI column in this issue presented by Birgit Seeliger and Bernard R. Hodgson

For a body such as the International Commission on Mathematical Instruction (ICMI), maintaining an archive of documents of various sorts is a responsibility of paramount importance. For those in a leadership position inside ICMI at a given time, this may serve as a source for first-hand background information about recent or distant episodes in the earlier life of ICMI. And for historians of today and tomorrow, archive material is of course crucial in the understanding of the development of mathematical education as seen from an international perspective. Keeping memory of the past is thus an act of social and scientific responsibility, not merely to honour the efforts of our predecessors, but more importantly to provide access to an essential tool for fostering an accurate image of the evolution of ICMI as a body, including moments of tension or significant phases in the decision-making process.

ICMI was established at the General Assembly of the 4th International Congress of Mathematicians (ICM) held in Rome in 1908 and has been a commission of the International Mathematical Union (IMU) since 1952,[1] so that the ICMI Archive is in fact a subset of the Archive of the IMU.

About the IMU/ICMI Archive

Since January 2011, the IMU Secretariat has been permanently based in Berlin, Germany. Under the supervision of the IMU Executive Committee (IMU EC), the Secretariat runs IMU's day-to-day business and provides support for the IMU operations, including administrative assistance for ICMI and the Commission for Developing Countries (CDC).

The IMU Secretariat also hosts the IMU Archive. Until 2010, the IMU Secretariat (and thus the Archive) was located with the IMU Secretary of the time. By the end of a term, documents were partially forwarded to the next IMU Secretary's office, and partially to the ETH Zurich University Archives [9, p. v], which kept original documents dating back to the early 1950s, when the IMU was re-established after the turmoil caused by WW2.[2] In a talk [10] presented at the inauguration ceremony of the "Archive room" within the premises of the Berlin Secretariat, Olli Lehto (1925–2020) spoke of the context which had led him, in the mid-1990s, to give the IMU Archive a new start by first agreeing to organize and catalogue the "largely unorganized archives of the Union" [9, p. v], and, eventually, arranging for the archives to be hosted at the University of Helsinki.[3] The idea of moving the IMU papers from Zurich to Helsinki had been raised for the first time in the 1980s by IMU President Jürgen Moser. In 1994, in view of the shortage of space in Zurich combined with the availability of new archive facilities at the University of Helsinki, the IMU papers were moved from Zurich to Helsinki [9, pp. v–vi].

Through his involvement as an IMU EC member (1975–1982) and IMU Secretary (1983–1990), Lehto had developed a profound knowledge of the IMU. Thanks to him, the records of the IMU – in spite of their "formidable" volume [9, p. v] – were sorted and catalogued at the University of Helsinki Archives and for the first time in accordance with the structure and historical development of the IMU, as announced in *IMU Bulletin* (see [6, 7]). Based on this material and on his direct experience and knowledge, Lehto subsequently published the first book devoted to the history of the IMU, *Mathematics Without Borders* [9], written at the invitation of the IMU EC [9, p. vi]. The very title of his book strongly reflects Lehto's belief in "the notion that the IMU is a large mathematical family transcending national borders" [9, p. 122].

Since its re-establishment in Berlin, the IMU Archive is now equipped with its own facilities, including IT support, and is run by a professional archivist,[4] in consultation with the two Archive

[1] Information on the context in which ICMI became a commission of the IMU can be found in in Olli Lehto's history of the IMU [9, Section 5.4 (pp. 108–113)].

[2] This pivotal archive role played by the ETH may be seen as following from the fact that two IMU Secretaries who served in the early years after the rebirth of the IMU in 1951, Beno Eckmann (1956–1961) and Komaravolu Chandrasekharan (1961–1966), both held a professorship in mathematics at the ETH.

[3] Those records form today the so-called Helsinki Subfond (SF1) of the IMU Archive in Berlin.

[4] Birgit Seeliger (since 2011).

Olli Lehto in 2011 at the Archive of the IMU, University of Helsinki. (Photo: IMU)

curators.[5] The process of archiving is based on general criteria including the authenticity, reliability, integrity, and usability of the material. As potential interest is not easy to assess, it is usually considered better to archive more than less.

The IMU/ICMI Archive, from paper to digital

The IMU/ICMI Archive holds both analogue and digital records. The latter induce new challenges, being in constant technological change per their own nature. Therefore, their life cycle management requires long-term preservation storage and formats to ensure the survival of their content.

The development of the Berlin Archive, in the early years following its inauguration in 2011, was closely monitored by the IMU Committee on Electronic Information and Communication (CEIC), in order to counter the risk of losing born-digital documents – mostly emails. Nowadays, a storage strategy based on a Linear Tape File System (LTFS) is employed to safeguard the rapidly growing electronic records. Born-digital data and digitized material are kept in their original form, as well as in a migrated and long-term readable format (PDF-A). The PDF files are readable with OCR. Using archiving software, they are enriched with indices and metadata so that various search functions are possible.

In that connection, every email sent to or from the official "@mathunion.org" addresses of both IMU and ICMI Presidents and Secretaries General gets automatically archived on the IMU server.

The content and scope of the IMU and ICMI Archive have thus in recent years greatly evolved and expanded, changing from traditional paper letters and documents to mostly digital records. The Helsinki Subfond (SF1) has been supplemented with other subfonds, mainly based on documents from former IMU Presidents and Secretaries General for the terms since the first catalogue (1996), as well as from officers of the commissions (including ICMI) and committees. The Archive is still being actively enlarged by searching and contacting various sources, sometimes outside the strict IMU/ICMI communities. For instance, scans of papers of Børge Jessen, IMU Secretary and EC member in the first years following the reincarnation of IMU after WW2, were obtained from the University of Copenhagen. Online and in-person searches by the IMU archivist were also made in several archives, among others at ETH Zurich and the Royal Academy of Belgium.

Efforts are also made to enrich the collection with books, pictures, and artefacts related to various IMU or ICMI events – notably the Proceedings of the International Congresses of Mathematicians (ICMs)[6] and of the International Congresses on Mathematical Education (ICMEs), the major quadrennial events of IMU and ICMI respectively. (The Archive even includes memorabilia such as t-shirts or mugs from both the ICMs and the ICMEs). These Proceedings usually reflect the state of the art in mathematics and/or mathematics education in the years preceding a given congress, and they generally contain original articles (for which the IMU sometimes holds the copyright).

Accessing the Archive: the IMU Archiving Guidelines

To ensure the consistency and stability of archiving, *IMU Archiving Guidelines* were prepared and endorsed by the IMU General Assembly in 2014 – with subsequent amendments by the IMU EC (most recently in December 2023 [8]). Cooperation and awareness between the producer of documents and an archive are not a matter of course. The guidelines thus include the commitment "to archive all documents/material created by the IMU President and Secretary General, as well as by officers of IMU commissions and committees, and that of IMU administrative staff. Further, IMU prize chairs/committees – including those of IMU commissions – have the obligation to provide material to the IMU Archive" [8, #3]. This stipulation provides the framework for a more complete accumulation of records than was previously the case. Moreover, in addition to the automatic storage of emails, a tool has been implemented that migrates them into long-term file formats by means of additional indexing. This ultimately makes it possible to include emails in the search across all the contents of the IMU Archive.

[5] Guillermo Curbera (2011–2020) and June Barrow-Green (since 2021) for the IMU, and Bernard Hodgson (since 2011) for ICMI.

[6] Though the IMU is known for its connection with the ICMs, not every ICM was organized under the auspices of the IMU, as described by Norbert Schappacher in his recent book [11].

It should be noted that the IMU Archiving Guidelines make provision for a three-tier embargo period – 0, 20 or 70 years – in connection with the level of confidentiality attached to each document. Examples of the latter include material archived by the committees for the various IMU prizes and awards (notably the Fields Medal), and the ICMI Felix Klein, Hans Freudenthal and Emma Castelnuovo Awards.

General information about the IMU and its commissions and committees, as well as documents of special interest (e.g., Proceedings of ICMs or ICMEs, reports of the IMU/ICMI General Assemblies, IMU and ICMI Bulletins/News, etc.), are available with open access on the IMU homepage[7] or the ICMI homepage.[8] Even though the IMU Archive serves to a large extent to support the work of the IMU and ICMI ECs, the material is also available for historical research (in accordance with the *IMU Archiving Guidelines*). To use the IMU Archive, an initial look at the "Finding Aids"[9] may be helpful, namely:

- the *Hierarchical thesaurus*, with a list of topics on the IMU and its commissions and committees, and
- the *Tectonic*, detailing the structure of the IMU Archive into subfonds, series and files.

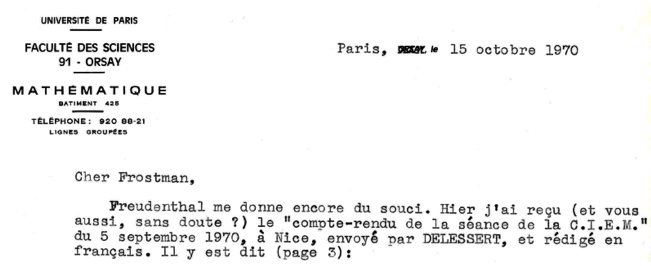
Work is in progress to make more material from the Archive freely available online via a search menu on the IMU website.

Despite its substantial collection, there are still gaps in the records of the IMU Archive. For example, print editions of the Proceedings of the first ICMs in Zurich, Paris and Heidelberg are still missing from the Archive's shelves. And moreover, there are no original documents covering the existence of the IMU or ICMI between 1920 and 1932. We are therefore always grateful to receive donations from the public, such as was the case recently with materials from the 1928 and 1954 ICMs which were donated to the IMU Archive.[10]

"Gold nuggets" from the ICMI Archive

Part of the ICMI Archive is made of books produced in the context of ICMI activities (ICME Proceedings, ICMI Study Volumes or Preproceedings, etc.), generally accessible both physically in situ and electronically. A most interesting part of the Archive comprises five boxes of paper documents – mainly letters – collected during the second half of the 20th century. A large portion of these goes back to the early days of the Archive, fewer paper documents having been filed in the years 1990–2010, as email was becoming the main channel of communication. The archived paper documents are mostly in English, with a few in French, German or Italian. Of notable interest are for instance documents related to moments of turbulence in the life of ICMI. Here are a few samples.

A delightful example in that connection is the *cri du cœur* from IMU President Henri Cartan, at the very beginning of a letter (15 October 1970) to IMU Secretary Otto Frostman: *"Freudenthal me donne encore du souci"* ("Freudenthal again causes me worries"). Cartan was then reacting to yet another impetuous move by ICMI President Hans Freudenthal, very near the end of his term, without even consulting on that matter the incoming ICMI President – see [3] or [5, p. 233] for details.


UNIVERSITÉ DE PARIS
FACULTÉ DES SCIENCES
91 - ORSAY
MATHÉMATIQUE
BATIMENT 425
TÉLÉPHONE : 920 88-21
LIGNES GROUPÉES

Paris, le 15 octobre 1970

Cher Frostman,

Freudenthal me donne encore du souci. Hier j'ai reçu (et vous aussi, sans doute ?) le "compte-rendu de la séance de la C.I.E.M." du 5 septembre 1970, à Nice, envoyé par DELESSERT, et rédigé en français. Il y est dit (page 3):

(…)


Bien cordialement

H. Cartan

Excerpts from a letter of Henri Cartan to Otto Frostman (15 October 1970). (Source: IMU)

Another striking moment, symptomatic of internal difficulties inside the 1979–1982 ICMI EC, is crystallized in a letter (September 1980) from Peter Hilton to the IMU Secretary, stating that he was presenting his resignation as ICMI Secretary on the ground that being expected by some of his colleagues, in his opinion, "to act in a purely 'secretarial' capacity, (…) [he] could not exercise the influence [he] hoped to have from that position" – see [5, p. 234]. However, for reasons (yet) unknown, this resignation did not materialize, and Hilton completed his term.

An episode of a more recent vintage, and thus connected to email archiving, is related to the dramatic change in the ICMI election procedure that occurred during the first years of this century, in reaction to a resolution adopted at the 2002 IMU General Assembly requesting the development by IMU of a new election scheme for IMU and its commissions. The general spirit behind this move was to lessen the influence of the outgoing IMU (and ICMI) EC on the next EC. It took a while for the IMU and ICMI ECs to agree on a scheme for the ICMI election that would meet the specificity of ICMI as a commission of IMU. Most of the discussions took place through a series of emails, some of which reached a somewhat

7 https://www.mathunion.org
8 https://www.mathunion.org/icmi
9 https://www.mathunion.org/organization/imu-archive
10 Information on these newly deposited IMU Archive materials can be found in the companion article by June Barrow-Green [1].

intense level, pointing to issues of "trusteeship" between IMU and ICMI, in contrast with recent "hard-won progress" in the relations between the two bodies. Eventually it was agreed to have for ICMI a Nominating Committee distinct from the one for the IMU EC election. And even more important: it was decided to transfer the ICMI election from the IMU General Assembly to the ICMI General Assembly, the first election under the new scheme being held in 2008. (A discussion of this episode, including references to Archive documents, can be found in [4].)

A fine example of the benefit gained by accessing archive documents is offered by the recent paper of L. Giacardi [2], proposing a selection of 69 archive documents (including four scan copies of original documents, three being handwritten). Among these documents, 44 belong to the IMU Archive, coming from the 1952–1966 and 1967–1980 ICMI boxes. Other documents belong to archives related to former ICMI and IMU officers. In the introduction to her paper, Giacardi points to the importance of having access to original correspondences and archival documents, so to better "reconstruct the spirit of an era in its various facets" [2, p. 137]. Moreover, providing access to the full document often provides a much stronger feeling for the background behind the issues at stake. This can be seen for instance in the letter (mentioned above) of Cartan to Frostman, which is quoted at length in [2, pp. 220–221], thus allowing the reader to develop a better sense for the crux behind this moment of tension in the IMU–ICMI relationship.

Conclusion

The records housed in the IMU/ICMI Archive richly reflect various aspects of the "life" surrounding mathematics and/or mathematics education from the early years of the 20th century up to the present day: for instance, how mathematicians and mathematics educators are interconnected at the international level through organizations such as the IMU and ICMI; what activities are necessary to foster the development of a mathematical infrastructure in all countries, including in connection with its teaching and learning; or what initiatives are taking place around the world to foster the enjoyment of mathematics – such as the International Day of Mathematics, an event led by the IMU and organized under the patronage of UNESCO each year on 14 March, since its inauguration in 2020, as a worldwide celebration aimed at students and the general public alike.

References

[1] J. Barrow-Green, Memorabilia from past ICMs recently acquired by the IMU Archive. *Eur. Math. Soc. Mag.* **133**, 56–58 (2024)

[2] L. Giacardi, The voice of the protagonists: A selection of unpublished letters. In *The International Commission on Mathematical Instruction, 1908–2008: People, events, and challenges in mathematics education*, pp. 137–238, Cham, Springer (2022)

[3] B. R. Hodgson, Once upon a time… Historical vignettes from the ICMI Archive: Episodes from the Freudenthal era. *ICMI News*, July 2019, 8–10 (2019) https://www.mathunion.org/icmi/icmi-news-july-2019#on-page-4

[4] B. R. Hodgson, Once upon a time… Historical vignettes from the ICMI Archive: The ICMI election procedure. *ICMI News*, July 2020, 11–13 (2020) https://www.mathunion.org/icmi/icmi-news-july-2020#on-page-8

[5] B. R. Hodgson and M. Niss, ICMI 1966–2016: A double insiders' view of the latest half century of the International Commission on Mathematical Instruction. In *Invited Lectures from the 13th International Congress on Mathematical Education*, pp. 229–247, Cham, Springer (2018)

[6] International Mathematical Union, Archives of the IMU as of June 1996. *IMU Bulletin* **40** (1996) https://www.mathunion.org/fileadmin/IMU/Publications/Bulletins/1994_1999/40/archives.html

[7] International Mathematical Union, Catalogue of the papers of the IMU. *IMU Bulletin* **40** (1996) https://www.mathunion.org/fileadmin/IMU/Publications/Bulletins/1994_1999/40/catalogue.html

[8] International Mathematical Union, IMU Archiving Guidelines. (2023) https://www.mathunion.org/fileadmin/IMU/Archive/IMU%20Archiving%20Guidelines_122023.pdf

[9] O. Lehto, *Mathematics without borders: A history of the International Mathematical Union*. Springer, New York (1998)

[10] O. Lehto, On the history of the archives of the International Mathematical Union. (Address given at the inauguration of the IMU Archive at the IMU Secretariat, 10 November 2011) https://www.mathunion.org/fileadmin/IMU/Archive/Olli_Lehto_speech.pdf

[11] N. Schappacher, *Framing global mathematics: The International Mathematical Union between theorems and politics*. Springer, Cham (2022)

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zbMATH Open – Where do we stand and what's next?

Christian Bär

After 7 very successful years as editor-in-chief of zbMATH Open,[1] my predecessor Klaus Hulek decided to hand over the baton to a successor. I was asked if I would be interested in this job and after a brief hesitation due to the time commitment involved, I decided to accept the challenge. One of the outstanding successes of my predecessor was certainly the transformation of zbMATH into an open access project, which was completed in 2021. This reorientation towards open science was recognized in June 2024 with the award of the first Demailly Prize for zbMATH Open.[2]

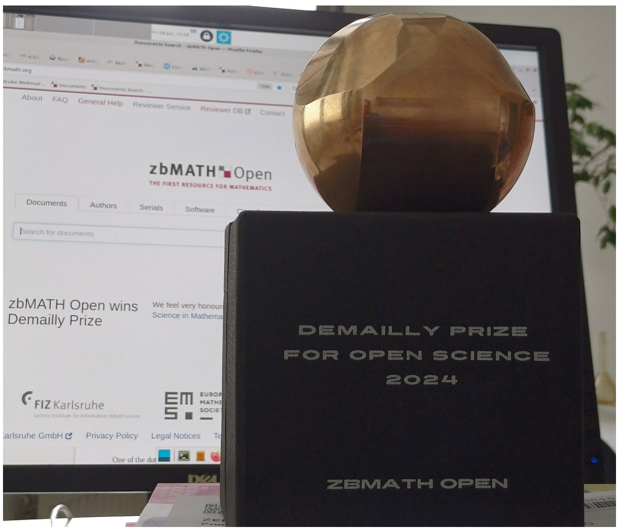
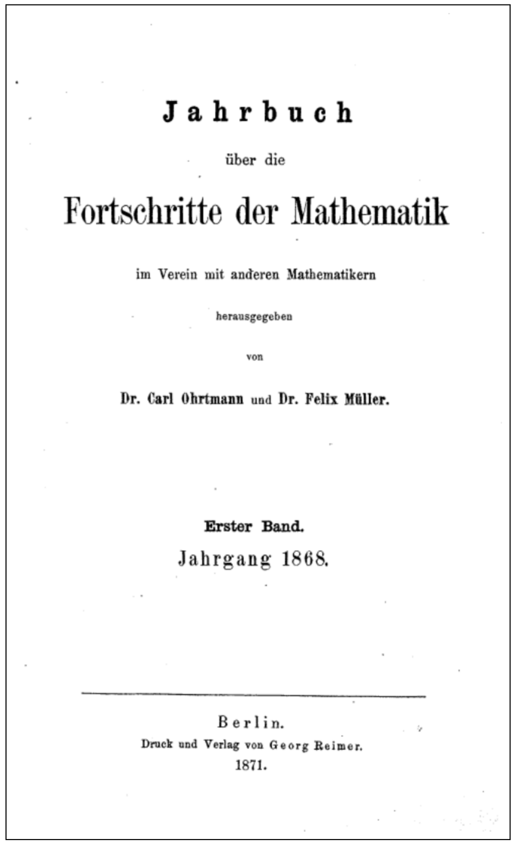


Figure 1. Demailly prize for zbMATH Open.

When the "Jahrbuch über die Fortschritte der Mathematik," which later was fused with the "Zentralblatt für Mathematik und ihre Grenzgebiete," first appeared in 1868, mathematical research data were essentially printed research articles and books. This was to remain the case for a long time. And the Zentralblatt was also



Jahrbuch

über die

Fortschritte der Mathematik

im Verein mit anderen Mathematikern

herausgegeben

von

Dr. Carl Ohrtmann und Dr. Felix Müller.

Erster Band.

Jahrgang 1868.

Berlin.

Druck und Verlag von Georg Reimer.

1871.

Figure 2. First edition of the "Jahrbuch."

published in printed form. I still remember how each volume of the Zentralblatt felt like it filled several meters of bookshelf and its use was associated with an endless amount of browsing. The younger ones among us probably can't even imagine that. In the early 1990s, after the Zentralblatt had become available electronically on CD, there were discussions in my institute whether we should continue to obtain the printed version. Some colleagues first had to get used to the idea of having a work only available electronically rather than in printed form. After a few years, however, this discussion came to an end.

[1] https://zbmath.org

[2] https://epiga.episciences.org/page/session-2024

However, technological progress has not only changed the Zentralblatt, but above all the mathematical research data itself. Today, articles and books are also available electronically. There is also mathematical software, databases, videos, discussions on internet platforms, numerical simulations, formalized libraries for machine-verifiable proofs and much more that is now also of great importance for mathematical research. Indexing and integrating this sometimes very heterogeneous research data is a major challenge for zbMATH Open. The "Deutsche Forschungsgemeinschaft" (German Research Foundation) has recognized the importance of this problem and is funding the "Mathematical Research Data Initiative" MaRDI.[3]

Today, zbMATH Open contains almost 5 million documents from around 1.3 million authors. There are summaries of around 1.2 million documents written by reviewers specifically for zbMATH Open. About 46,000 software packages are referenced with cross-references to and from articles in which they play a significant role. There are references to various databases such as the "On-Line Encyclopedia of Integer Sequences"[4] or the "Digital Library of Mathematical Functions"[5] and to mathematical discussion platforms such as "MathOverflow".[6]

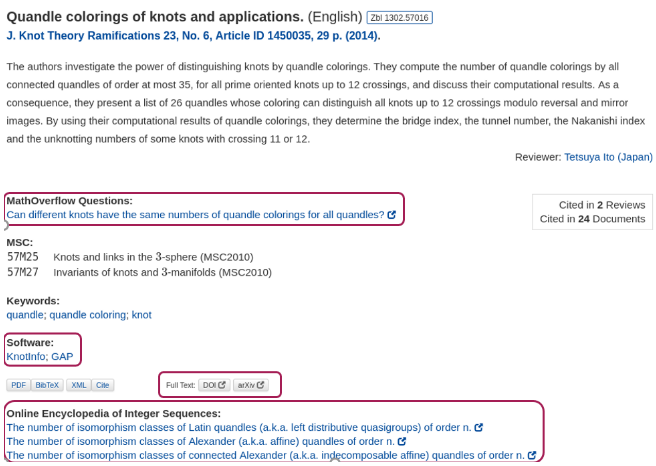


Figure 3. Document review with links to various research data.

A significant new enhancement is the integration of arXiv preprints. These are recorded as a separate document type and merged with the published version after publication. This has various advantages for users. When searching for relevant literature, it is no longer necessary to carry out two searches, one in zbMATH and one in arXiv. The zbMATH database is much more up-to-date and there is now no longer just a link to the published version for the indexed documents, which may be behind a paywall, but also to the freely available arXiv version.

To make zbMATH as user-friendly as possible, the web interface is currently being revised. In addition to the familiar one-line search for more experienced users, a new, completely self-explanatory and intuitive search mask will be offered, which should be available by the time this article is published.

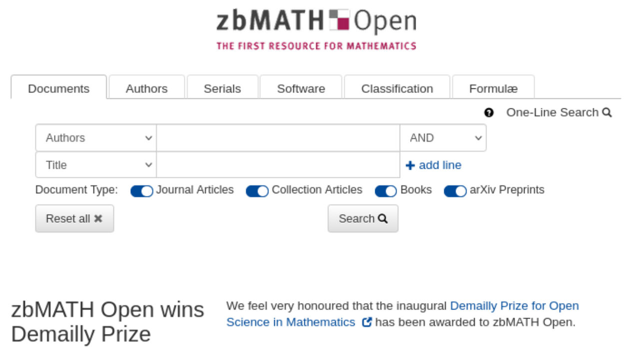


Figure 4. New search mask of zbMATH Open.

Anyone wishing to offer a service that uses zbMATH Open data is invited to do so, in keeping with the open nature of zbMATH Open. The new powerful application programming interface, the so-called REST API,[7] allows automated access with comprehensive filter functions.

The integration of further mathematical databases and other research data such as videos or formalized mathematics is the subject of lively internal debate. The benefits must always be weighed up against the costs. Sooner or later, there will probably be no way around it.

The spectacular advances in artificial intelligence, especially large language models, pose a particular challenge. Specially trained GPTs such as "Math Solver"[8] are already able to provide reasonably meaningful explanations of simple mathematical questions, including references to the literature. It is to be expected that this technology will be further perfected in the near future. Imagine a language model that can provide reliable and comprehensive answers to mathematical questions in the field of current research based on zbMATH's treasure trove of carefully curated data. What sounded like science fiction a few years ago may now be within the realm of possibility.

[3] https://www.mardi4nfdi.de
[4] https://oeis.org
[5] https://dlmf.nist.gov
[6] https://mathoverflow.net
[7] https://api.zbmath.org
[8] https://studyx.ai/math-solver

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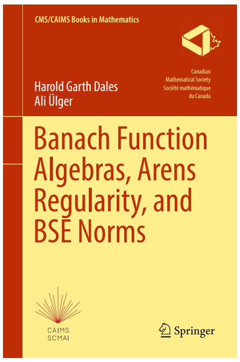
Book review

Banach Function Algebras, Arens Regularity, and BSE Norms
by Harold Garth Dales and Ali Ülger

Reviewed by Betül Tanbay



To the memory of Garth Dales.

Mathematical learning and mathematical research are being severely affected by technology in general, by the internet and artificial intelligence in particular. The pandemic accelerated the change. The mathematical community is discussing all over how knowledge should be created and transmitted, what the speed and the means of sharing should be.

In the middle of this discussion, discretely a book shone after almost a decade of hard work by Garth Dales and Ali Ülger. At an earlier time it would have become immediately a classic. I dare to claim that it is also a classic-to-be for reasons I must explain before I get in the details of the book.

The collective mathematical memory is rather peculiar. The history of mathematics is full of surprises, of problems solved using some seemingly unrelated results in a forgotten topic. Today, many classical fields of mathematics are being treated as obsolete, forgotten regularly at graduate courses, getting less and less research funds. We are at a moment of history where the letters A and I are to appear in any research grant application to achieve acceptance. Young mathematicians are in a huge rush of publishing, bibliometrics seem to have won over insight.

Despite this rush, Garth Dales and Ali Ülger took their time. They started this book when they were both in their seventies, as established researchers in the area. They have worked at distance regularly throughout years, making sure to have a few face to face weeks per year to settle the amassed material. When an open question rose, in the midst of a chapter, they did not avoid it. Real research got in the way. It was sad for the co-author but also for many of us who followed their work, to lose Garth before the book appeared in public.

This "slow research" style resulted in a book that can be used as a course book for a graduate class, but also comprising new unpublished results in the topic and new proofs of known results. After very shortly reminding of the history of the subject, I shall start by tracing how this book can be used as a course book, and mention some of the new results.

The Banach algebras, as a subject, is one of the largest components of functional analysis, with its own problems and techniques. Since its introduction during the second world war, the subject has grown tremendously. Banach algebras are fed essentially by three sources: operator theory (C^*-algebras, von Neumann algebras), harmonic analysis (group algebras, semigroup algebras, measure algebras) and complex analysis (uniform algebras). And there are a multitude other Banach algebras obtained through various constructions such as projective tensor product, direct sums, taking quotients, etc. Although the main emphasis of this very rich book is on commutative semisimple Banach algebras, it also contains many results about non-commutative Banach algebras.

The book consists of six chapters. In the first chapter, the authors fix the notation and the terminology and mention a series of known results in measure theory, bounded linear operators, tensor products of Banach spaces and the geometry of Banach spaces to be used in subsequent chapters.

In Chapter 2, the authors give some information about Banach algebras in general, and C^*-algebras, von Neumann algebras and dual algebras in particular. In this chapter the topic of Arens products and the second dual of Banach algebras equipped with an Arens product are also treated. I mention here two nice results in that chapter that attracted my attention. (1) Theorem 2.2.25, which says that the dual space of a C^*-algebra A has the Schur property iff the sequence space ℓ^2 is not a quotient of A. (2) Corollary 2.2.26, which says that the dual space of the projective tensor product $A \hat{\otimes} B$ of two C^*-algebras A and B is weakly sequentially complete iff A^* or B^* has the Schur property. These results, as far as I know the subject, are new.

In Chapter 3, the authors introduce the notions of Banach function algebras (i.e., commutative semisimple Banach algebras), sequence algebras, projective tensor products of commutative C^*-algebras and uniform algebras. Two important and recent subjects in this chapter are the so-called "separating ball property (SBP)" and the "bounded pointwise approximate identities (BPAI)." A Banach function algebra A is said to have the SBP if giving two distinct characters φ and ψ, there is an a with $\|a\| \leq 1$ such that $\langle a, \varphi \rangle = 1$ and $\langle a, \psi \rangle = 0$. This property and its variants have a multitude of applications for the existence of BPAI's in the maximal ideals of the algebra, the existence of idempotent elements, the existence of topological invariant means for abstract Banach function algebras and Arens regularity.

In Chapter 4, the authors introduce and give the basic properties of three classes of Banach algebras that come from harmonic analysis: first, the group algebra $L^1(G)$ and the measure algebra $M(G)$ of a locally compact group (G), then the Fourier algebra $A(G)$ and the Fourier-Stieltjes algebra $B(G)$ of a locally compact group G, introduced by Eymard and finally the Figà–Talamanca–Herz algebra $A_p(G)$ and $PM_p(G)$ of an amenable group G. The authors study various properties of these algebras, including problems concerning when these algebras have bounded approximate identities, when there are ideals in their biduals, and they ask what are their spaces of weakly almost periodic functionals and their multiplier algebras.

In Chapter 5, the authors study the Bochner–Schoenberg–Eberline algebras, the so-called BSE algebras. Let G be a locally compact Abelian group with dual group $\hat{G}$. The BSE theorem gives an inequality that is necessary and sufficient for a continuous bounded function f on $\hat{G}$ to be the Fourier–Stieltjes transform of a measure $\mu \in M(G)$. A BSE-function on the character space of a Banach function algebra A is a continuous function that satisfies the condition in the BSE theorem. The algebra A is said to be a BSE algebra if the Gelfand transform of each multiplier of A satisfies the condition in the BSE theorem and, conversely, if any continuous bounded function on the character space of A satisfying this condition is the Gelfand transform of a multiplier of A. These notions were introduced by Hatori and Takahasi in 1990. Since then quite a few results accumulated about these notions. The authors give a functional analytic treatment of these notions, expose the known results and present several new results, especially about the question when the multiplier algebra of a Banach function algebra is a BSE algebra and when the norm of the algebra A is equivalent to its BSE norm.

Finally, Chapter 6 is about Arens regularity and the topological centres of the second dual of a Banach algebra. In this chapter the authors expose a series of known results in the area together with some new results. The new results are mainly about Arens regularity of the projective tensor product $A \hat{\otimes} B$ of two Banach algebras A and B. To mention just one: Theorem 6.2.13 states that, if both algebras A and B are Arens regular and the algebra A has a bounded approximate identity, then a necessary condition for the algebra $A \hat{\otimes} B$ to be Arens regular is the weak compactness of every bounded linear operator $T\colon A \to B^*$.

The book is well-written; it is very rich in ideas and approaches. The subjects dealt with are clearly explained and illustrated by numerous examples; and the known results are well-referenced: there are 332 references. The index of symbols and the index of terms are quite rich and facilitate the job of the readers. I do hope that the book will help keeping alive careful and deep thinking in pure mathematics.

Harold Garth Dales and Ali Ülger, *Banach Function Algebras, Arens Regularity, and BSE Norms.* CMS/CAIMS Books in Mathematics, Springer, 2024, xii+445 pages, Hardcover ISBN 978-3-031-44531-6,
eBook ISBN 978-3-031-44532-3.

Betül Tanbay is a professor of functional analysis at the Boğaziçi University in Istanbul. She was founder and first co-director of the Istanbul Center for Mathematical Sciences. She was the first female president of the Turkish Mathematical Society, and she has also served and serves in many committees of the IMU or EMS. Tanbay received her undergraduate degree from the Louis Pasteur University, Strasbourg, and her graduate degrees from the University of California, Berkeley. Currently, Betül Tanbay is the chair of the Steering Committee of the second Balkan Mathematics Conference to take place in Thessaloniki in June 2025.

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DOI 10.4171/MAG/218

Illustrating Emmy Noether

Constanza (Coni) Rojas-Molina

"Named after Emmy Noether" shows a selection of things and activities inspired by Emmy Noether.

Since 2018, Constanza Rojas-Molina (Coni) has worked around the image of Emmy Noether, one of the most important mathematicians in history, exploring her life and work with illustrations. In 2018, Rojas-Molina created #Noethember,[1] a drawing challenge on Twitter, with the support of the maths blog The Aperiodical (UK). In the following years, #Noethember has been published on maths websites in several countries and languages. Rojas-Molina participated in the Exhibition about Emmy Noether organized by C. Fermanian Kammerer at the Institut Henri Poincaré in Paris in 2023.[2] During the first artistic residence for mathematicians at the University of Angers (France) in November 2023, A. Panati, C. Fermanian Kammerer, N. Raymond, and Coni polished and gave life to Panati's theatre play about Emmy Noether.[3]

Coni is a mathematician at CY Cergy Paris University, France. She is also a science communicator and illustrator. Her preferred formats are sketchnotes and comics. You can see her work at crojasmolina.com.

hello@crojasmolina.com

[1] https://crojasmolina.com/illustration/noethember-drawings-about-emmy-noether

[2] https://www.ihp.fr/fr/actualites-science-et-societe/emmy-noether-mathematicienne-dexception

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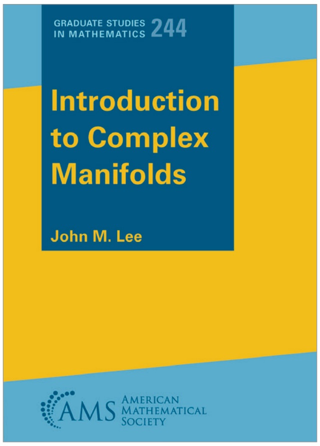

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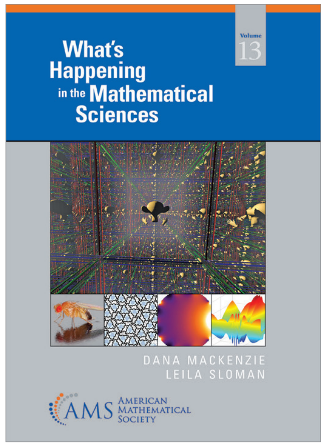

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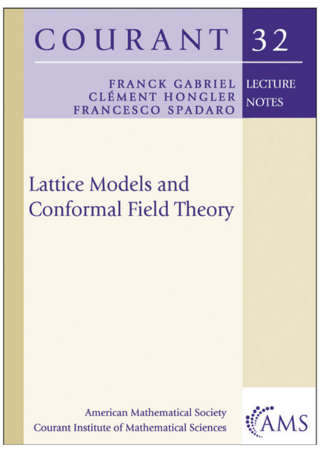

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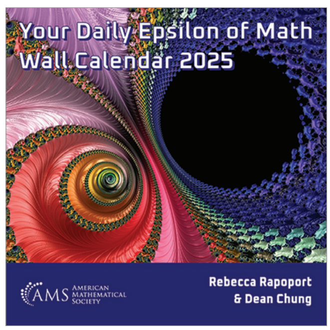

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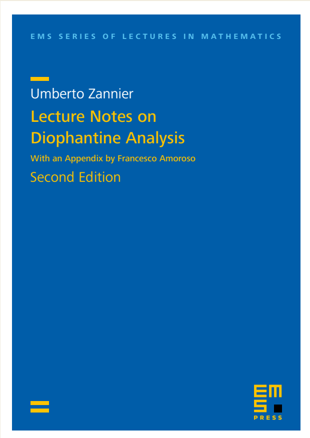

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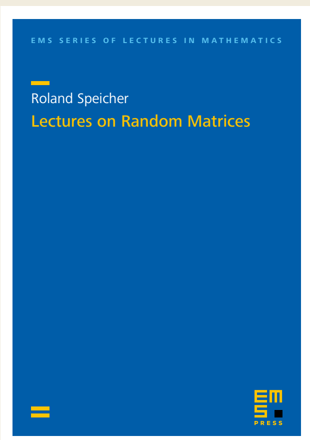

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