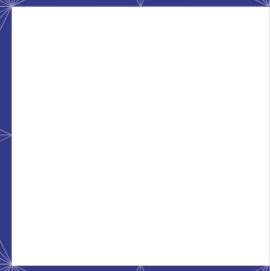




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THE MAISON POINCARÉ

BRIDGING THE GAP BETWEEN
MATHS AND THE SOCIETY

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The origins

Foundation of the Institut Henri Poincaré

Ever since its creation by the mathematician Émile Borel¹ almost a century ago, the Institut Henri Poincaré has promoted and hosted scientific exchange at the highest international level.

The institute (IHP in short) is named after the French mathematician, theoretical physicist, and philosopher of science Henri Poincaré². It was built on a small campus in central Paris in the aftermath of World War I, next to Marie Curie's radium institute and Jean Perrin's laboratory on physical chemistry. Like the institute for physical and chemical biology built next to it in the same years under the impulsion of Jean Perrin³, the Institut Henri Poincaré was the conjugated result of a few prominent scientists' vision and of an incentive by private foundations – Rockefeller and Rothschild – aiming at renewing French science, with the approval and support of the French government and of the Faculty of Science of Paris University.

In between the two world wars the atmosphere in those brand new brick buildings was made of intellectual emulation nourished with operation means that were incomparably better than at the Sorbonne. This emulation was actually not limited to scientists. In the spirit of the journal *La Revue du mois* that Borel and the writer Camille Marbo – who happened to be his wife - edited in the first quarter of the century, with Perrin in the editorial board and this was no chance, tea parties were being held on a regular basis in Perrin's laboratory tea room.

The figures of Borel and Perrin

Borel, who was holding the chair of probability and mathematical physics, would promote what we now call cross-disciplinary fertilization, that is exchange between mathematics and their applications in other sciences – in particular physics and biology. He also worked at bridging the gap between maths and the society, coining the term social mathematics (Borel 1914).

Besides his remarkable scientific carrier, the physics Nobel prize winner Perrin is also known for having founded the famous *Palais de la découverte* in Paris, where generations of pupils, students and laymen enjoyed getting acquainted with scientific issues until its closure this year for rehabilitation work.

The two men were not only friends of the same age. Their actions and fate were undoubtedly intertwined. In particular, Perrin was at Borel's side in the initial IHP board of directors. It is also worth mentioning that Borel was involved in initiatives that eventually led to the

¹ (1871–1956)

² (1854–1912)

³ (1870–1942)

foundation of the CNRS (French National Centre for Scientific Research), obtained by Perrin from Blum's government⁴.

Villani and the house of mathematics

The *Maison Poincaré* project led by the institute is faithful to this heritage made of topmost science and outreach. It was initiated as soon as 2011 by the former IHP director Cédric Villani. The Université Pierre et Marie Curie⁵ agreed to reallocate Perrin's laboratory building to IHP after the LCPMR⁶ research teams moved to modern premises on the Jussieu campus. Meanwhile, Villani also managed to convince policy makers of the city of Paris, the region Île de France, the French government and the CNRS to support an ambitious refurbishment work that would eventually enable the building to host further international scientific activities and an innovative sort of maths museum, in central Paris, with the purpose of bridging the gap between maths and the society.

The secured, overall budget on public funds is worth 23 million euros. This includes the construction work and layout of the building together with the conception and realization of the museum. To support the operating costs, Villani founded with the supporting institutions and private partners an endowment fund. Since its creation in 2015, the IHP endowment fund has raised 1,7 million euros from companies and individuals.

The Maison Poincaré project

Originally referred to as the *Maison des mathématiques*, words which also stand for the whole IHP since its renovation in the 1990s (Villani, Uzan and Moncorgé, The house of mathematics 2017), the future maths museum and more generally the new IHP department dedicated to raising public awareness and maths communication towards the general public has been named the *Maison Poincaré*. This name reflects the fact that it does not only deal with mathematics but also with their interactions with other disciplines, among which the physics plays a special role.

Speaking of other disciplines, it would be anachronistic to associate the name of Poincaré with computer science. However, as the reader might not know, the Institut Henri Poincaré could have, and almost did become the cradle of computer science, at least in France, during WWII (Mounier-Kuhn 2010). Computer science, or *informatique* as we call it in French, will not be forgotten in the Maison Poincaré.

Remarkably enough, after proving to be as convincing as was Perrin to raise public and private funds to support ambitious projects, Villani engaged in a political career in 2017 and became a member of Parliament, as was the first IHP director Borel. He subsequently left to his

⁴ The launch of the CNRS was actually delayed and happened just after the outbreak of World War II.

⁵ UPMC, which later merged with Université Paris Sorbonne to make Sorbonne Université, founded January 1st 2018.

⁶ Laboratoire de chimie physique - matière et rayonnement (LCPMR), the official name of Perrin's former laboratory since the 1990s.

successor Sylvie Benzoni, appointed on January 1st 2018, the daunting task of carrying out a 23 M€ extension project, and of developing further the institute's missions and transforming its organization in order to make the Maison Poincaré a reality.

The architectural and museography prefiguration of the project actually began in 2015. Despite the change of the institute's directors, there has been stability both in the project spirit and in the stakeholders. Marion Liewig was appointed project manager and head of development as early as 2016. The architects and scenographers were chosen in 2017, with an estimated opening date of September 2020 – we were speaking of the *Maison des mathématiques 2020* at that time. We now foresee an opening of the *Maison Poincaré* at the end of 2022.

Current context

To summarize what has been said so far, the *Maison Poincaré* project is led by the Institut Henri Poincaré, a research and training centre founded in 1928. It will be hosted by 2022 in a refurbished building.

The district where IHP is located and thus also is the future Maison Poincaré is mostly frequented by university students, intellectuals and researchers. Few tourists, families or schools actually visit that district. One of the main goals of the Maison Poincaré is to attract and open doors to a large variety of people, ranging from high-school students and teachers to occupational users of mathematics, art amateurs and laymen. Of course we hope that it will also attract people already keen on mathematics, but this is not the main purpose.

The project has arisen in a rather paradoxical context. France is praised for the excellence of its mathematical elite, but on average pupils and students perform poorly in international assessment surveys⁷. Maths curricula have been revised over the years, but the situation has worsened.

It turns out that the latest reform was based on a report (Torossian and Villani 2018) co-authored by the IHP former director and initiator of the Maison Poincaré project, Cédric Villani.

Despite its good intention that reform has had the effect of drastically reducing the number of high-school students learning mathematics⁸. Maths options in high-school are perceived as too difficult, and students refrain from choosing them in dramatic proportions. Unfortunately,

⁷ PISA <https://www.oecd.org/pisa/publications/pisa-2018-results.htm>

TIMSS <https://timssandpirls.bc.edu/timss2019/>

⁸ This has been reported to policy makers by various associations and learned societies, e.g. the SMF <https://smf.emath.fr/actualites-smf/0320-lettre-ouverte-cpu-reforme-voie-generale-lycee-enseignement-mathematiques>, and in the general media, see e.g. <https://www.nouvelobs.com/education/20201127.OBS36684/info-obs-comment-la-reforme-du-lycee-a-eu-la-peau-des-maths.html>.

this effect is even worse on girls, who are traditionally more reluctant than boys to engage in maths in Western societies and in France in particular⁹.

Nevertheless, secondary schools desperately need maths teachers. This occupation is not attractive enough. The hiring of maths teachers has been difficult for many years, with too few candidates, and candidates who do not meet basic requirements¹⁰.

Last but not least, a fact that is apparently not specific to France is that many people – including policy makers - proudly claim they are very bad at maths, in a world where maths has never been so ubiquitous. This has been emphasized by the Covid-19 crisis, which has shown severe deficiencies in the general level of understanding of basic mathematics.

This dire context gives us a strong motivation for building the Maison Poincaré. We undertake the challenge of contributing to reverse the situation from several perspectives.

There are scores of specialists in the world working on ways of bridging the gap between maths and the society. We may think for instance of the two concurrent series of international conferences, Mathematics Education and Society Conference¹¹, and International Congress on Mathematical Education¹².

At IHP we are happy enough to have acquired means to take action in mathematical science communication, if not directly in mathematics education. We aim at implementing various ways of developing *mathematical acculturation*, in the most positive sense of this term.

The Maison Poincaré will include a permanent exhibition (presented in § **The permanent exhibition** page 11) and various outreach activities in connection with it or to be set up in our premises (see § **Guided tour of the premises** page 7) or outside the walls in collaboration with our partners. Our experience of outreach activities so far and some plans in this regard are described in § **Outreach activities** (page 20). Finally, shorter parts are devoted to discussion of our assets (§ **Assets** page 24) and our challenges (§ **Challenges** page 25).

Guided tour of the premises

A heritage building

⁹ The proportion of girls choosing maths in their last high-school year has been divided by 2 after the latest reform.

¹⁰ For the last decade, the national competition for hiring secondary school maths teachers, CAPES, has been recruiting fewer people than the number of open positions, see https://capes-math.org/data/uploads/Reunion_formateurs_2020.pdf.

¹¹ <https://www.mescommunity.info/>

¹² <https://www.mathunion.org/icmi/conferences/icme-international-congress-mathematical-education>

We are in the heart of Paris, just behind the Panthéon, in a district renowned for its academic institutions. The Maison Poincaré is to be hosted in Perrin's former laboratory¹³ after its complete refurbishment. The whole building is next to the Institut Curie, a cancer research institute which includes a hospital, and also a small but very interesting museum¹⁴.

Perrin's building consists of a three-storey L-shaped building, also endowed with a four-storey copper roofed dome that used to be an observatory¹⁵. The Maison Poincaré will basically occupy the ground floor and the basement, which will be both open to the public given that the dedicated teams will have office space and meeting rooms on the first floor. Also open to the public will be the ground floor terrace opening on to the garden.



Picture 1 Artist view of terrace viewed from lecture hall. ©Atelier Novembre (architect) and Du&Ma (scenographer)

A welcoming place

The entrance hall of the building will be a crossroad for the public, the IHP teams, and the researchers working in the upper floors. Its wood panelling will be enhanced with modern amenities, in particular an information screen and an optical theatre introducing the Maison Poincaré symbol, the bronze Rulpidon¹⁶ to visitors.

¹³ There is actually a current research department named after Jean Perrin at Sorbonne Université (<https://sciences.sorbonne-universite.fr/structures-de-recherche/laboratoire-jean-perrin>) but it is distinct from the LCPMR.

¹⁴ The musée Curie <https://musee.curie.fr/>

¹⁵ This observatory is reminiscent of the Sorbonne astronomy tower, built at the end of the XIXth century.

¹⁶ A monumental version of which will be installed in the garden, see Picture 1.

On the right of the entrance will be the reception desk, a small shop and café. For reasons of space constraints in this heritage building, the cloakroom will be located downstairs in the basement.

The spacious basement will receive temporary exhibitions, primarily those designed by the Maison Poincaré or its partners, but it will also be open for rent to exterior exhibitions. Indeed, the revenue of space rental is an important part of the business model for the extended IHP.

Moreover, a 100 m² activity room will be fitted out for our science communicators to engage with groups of pupils and their teachers. In the temporary exhibition space, visitors will have the opportunity to spot under a glass cover the 30-meters deep well that used to lead to underground experiments.

The ground floor premises can be described as follows, with an alternation of heritage spaces that will be renovated to basically return them to their original state, and of newly fitted out spaces.

Wooden atmosphere

When entering the corridor on the left on the entrance hall we get to discover Perrin's tea room, with its parquet floor, its wooden display cases on almost 360 degrees, its sliding chalk board, and its sink.



Picture 2 Perrin's tea room before renovation. © Camille Cier

Next to this room is Perrin's lecture hall. It is a traditional amphitheatre with wooden benches and tables, a wide desk and a sliding chalk board from which Perrin himself would lecture. We can access it through a small door from the tea room, or from an elegant columned passageway from the corridor.



Picture 3 Perrin's lecture hall before renovation. © Camille Cier

The rear wall of the lecture hall is decorated with a fresco by Émile-René Ménard, surrounded by the incipit of *Les atomes* (Perrin 1913), a best-seller book of its time where Perrin gives an overview of the early XXth century physics, and in particular his own discoveries that led him to be awarded the Nobel prize in 1926.

The rest of the ground floor is at the moment a largely open space, save for Perrin's former office, with its chimney and again parquet floor.

Modern layout

The architects of the project have designed three new spaces there. There will be a kind of foyer, with an open view on the garden and large stairs on which the public can sit. Next to the foyer will be a large gallery, both spaces being open on each other. Finally, as large as a ballroom will be a mostly empty space, Alice's room, to be dedicated to a most innovative popularization experience through mixed reality technique.

All spaces will be fully accessible to physically impaired people, except the steps and the bottom of the amphitheatre plus some parts of the terrace, for technical reasons. The basement, the passageway to and the top of the amphitheatre itself – some 75cm above the general ground floor level – and the main part of the terrace will be accessible with the same

lift from the entrance hall, itself accessible from the alley level through a ramp. A separate lift will give access to the garden from the terrace.

Valid people will access the basement either by the staircase next to the entrance hall or by a newly created staircase in between the foyer and the garden.

Other floors will be accessible to authorized people only, either by the staircase next to the entrance hall or by a newly created staircase in between Perrin's office and Alice's room, open on the terrace. Of course disabled people will be allowed to use the lift to go upstairs.

Table 1 *Surface figures*

Ground floor	450 m ²
Basement	450 m ²
Garden	150 m ²
Terrace	150 m ²
Rest of the building	1100 m ²

The permanent exhibition

Ambition and target

Numerous myths surround mathematics. Even when debunked, see e.g. (Kogelman and Warren 1978), maths myths persist in the society and in the students' mind. Let's quote a few of them, which we think contribute a lot to the bad reputation of mathematics. Maths require arid logic, not intuition. Maths is not creative. There is nothing new to discover in maths, its knowledge body has been stuck since the antiquity (Pythagoras) / the 8th century (Al-Khawarizmi) / the 17th century (Fermat/Newton)¹⁷. Maths is useless, it has nothing to do with daily life. Not to mention the all-too-common misconception that men are better at maths than women¹⁸.

We aim at deconstructing the bad reputation of mathematics in various manners. We plan to do so in particular by opening up the public to hidden and / or surprising mathematics on a variety of topics than can pique their interest, for instance starting from objects from daily life (e.g. soccer ball) or situations (e.g. crowd evacuation).

¹⁷ The vast majority of people would choose the first option, believing that maths stopped with Pythagoras.

¹⁸ This belief is rooted in even worse ones that were shared by the most prominent scientists until very recently, see e.g. this quote by the physicist Richard Feynman in 1966: "I didn't realize the female mind was capable of understanding analytic geometry."

(<http://www.feynman.com/science/what-is-science/>)

Our ambition is to convince visitors that mathematics and their applications form a huge, lively, and crucial field of science and technology. This is important to have more young people engaged in this field and related ones. This can help to comfort mathematics teachers in their job¹⁹.

On a more general ground we want to demonstrate to visitors that mathematical thinking is of great help to understand the world, and also to make decisions in daily life. Anyone can gain from it. Anyone can belong, including of course girls and women and people from diversity.

The main originality underlying this project compared to other science or maths museums is that it is supported and hosted by a research institute²⁰. It is important for our supporting institutions (CNRS and Sorbonne Université), the other public funders (the city of Paris, the Ile de France region, the French state), and our private partners through the IHP endowment fund that we convey research topics, and that we bridge the gap between researchers and the public.

Visitors will have the opportunity to meet and exchange with researchers hosted at IHP. Beside the classical format of public lectures, researchers will be encouraged to interact with the public through a renewed tradition of tea parties in Perrin's former tea room. The café by the entrance, the multiple terraces of the building, and the garden equipped with a blackboard and a full-scale version of the Maison Poincaré symbol – a mathematical sculpture called Rulpidon – will also be pleasant places for researchers and the public to meet and chat. This will enhance the role of the institute in the society, and participate in our demystifying endeavour.

Our purpose is to reach the widest possible audience from the age of 14, from the most reluctant people to the most enthusiastic ones, make them discover what research in mathematics and applications is, and allow them to encounter the men and women who are working in those fields. We have been working with associations and the three regional academy directorates (Créteil-Paris-Versailles) to get in touch with students from diverse backgrounds and their teachers. We have also been working with art schools, museums, and a movie theatre (see § Partnerships page 25 for a few more details). We communicate on a regular basis on social networks (Facebook, Instagram, Twitter, YouTube), and send

¹⁹ To quote Bishop (Bishop 1998), “in my experience there are few teachers of Mathematics [...] who consider that they are themselves Mathematicians [...], or even that the Mathematics which they teach has any particular values. [...] They could be acculturating their students into believing that they are learning Mathematics for its benefits as applicable knowledge, or to have pleasure in its finest or most intriguing discoveries or inventions, “for its own sake”, or even to train their minds.”

²⁰ We are not aware of any other example, save for the small Museum für Mineralien und Mathematik Oberwolfach linked to but not exactly in the premises of the Mathematisches Forschungsinstitut Oberwolfach (<https://www.mima.museum/?lang=en>), even though many institutes do offer outreach activities (e.g. the Perimeter Institute <https://www.perimeterinstitute.ca/outreach>).

newsletters to our several thousand entries database drawing attention to our outreach activities.

In doing so we have the ambition of contributing to raise public awareness of the importance of mathematics for contemporary society, and to encourage more young people to engage in mathematics and their applications in technology and the society. In order to achieve this goal we need to convince the public that mathematics is a vivid field with lots of occupational opportunities, and make this visible in the media and social networks.

This will be done in particular by drawing the attention to men and women with diverse trajectories that have been strongly influenced by mathematics, and by pointing out unsuspected, close links between academic research, applied research, and innovation. If not as playful as other maths/science museums, our permanent exhibition is intended to be inclusive and induce astonishment, to arouse curiosity, to raise questions and create wonder.

Our main target audience is the population of high-school students²¹, teachers²², and those people in the general public who have an interest for science, even more so if their interest comes from indirect paths - e.g. through art or humanities. We have acquired some experience in this respect, as we explain below (§

Assets, page 24).

We shall pay special attention to targeting less privileged zones and to attracting schools from priority education zones, as we have already done in various outreach initiatives. For instance we have organized visits and public lectures with the *Institut Télémaque* (mentioned § Partnerships page 25). Furthermore, the IHP director Sylvie Benzoni is engaged in a training program for maths teachers of the whole academic region Créteil-Paris-Versailles.

She has also been building special links with a middle-school in Saint-Denis (northern suburb of Paris), which has chosen her as a role-model among other female scientists. The students of that school will certainly be the first to test some of the Maison Poincaré hands-on. We are going to work with the association *Science ouverte* (also mentioned in § Partnerships page 25) to open this possibility to more schools from that area.

We are also convinced that we have a role to play in conveying scientific culture more broadly. In this we rely in particular on journalists, science journalists but more importantly those from the general, national media (e.g. *Le Monde*) or cultural ones (e.g. *Beaux-arts magazine*). We already interact with a number of them on a regular basis, thus providing help to enlarge their scientific network and contributing to spread the word about scientific stakes. We plan to reinforce initiatives towards the media in the Maison Poincaré.

Finally, we aim to involve the international visitors participating in IHP research programs more with outreach efforts at the Maison Poincaré. Some of them are already willing to

²¹ And also advanced middle-school students.

²² We would in particular like to attract teachers from other disciplines or primary school teachers who were not originally trained at science.

contribute to raising public awareness, others need to be encouraged, as we have experienced in the last couple of years when asking for public lectures. Encouragement might come, for example, from specific additional financial support to stay at IHP and engage in a mathematical communication project.

Design method

At first the permanent exhibition project was being discussed between the IHP directors - Cédric Villani, Jean-Philippe Uzan and then Sylvie Benzoni, the project manager Marion Liewig, and the scenographer, Rémi Dumas (Du&Ma) working with the architect (Atelier Novembre) in charge of the building's refurbishment.

The need for a curator was soon identified if we were to make any progress in designing the contents of the museum's program. This is how Céline Nadal (MuseoScience), a museographer originally trained at advanced physics came into play. She started to work for the project in 2019 and she is to continue until its opening in 2022. Her role is most important to lead the workgroups and adapt for the public the content imagined and/or produced by the researchers involved in the project.

Before and while working on the museum's program we have visited several science museums at various places in the world to get some inspiration, references and points of comparison. Visits were made abroad at the *MoMath* in New York, the *London Science Museum*, the *Manchester Science Museum*, and the *Mathematikum* in Giessen. In France we are in close contact with the *Palais de la découverte*, the *musée Curie* and the *Espace des sciences Pierre-Gilles de Gennes* (ESPGG) in Paris, the *Maison des mathématiques et de l'informatique* (MMI) in Lyon, and *Fermat Science* near Toulouse. This has been helpful for us to better define our positioning and to think about our future exhibits. Some non-scientific museums such as the *Deutsche Kinemathek* in Berlin or the *Hélène and Édouard Leclerc foundation for Culture* in Landerneau have also been great sources of inspiration.

Three major principles have been underlying the design of our permanent exhibition.

1. Displaying topical mathematics embodied by contemporary men and women involved in mathematics or connected fields.
2. Paying attention to gender equality, diversity, and accessibility.
3. Managing the project on a cooperative and collaborative manner.

In the spring of 2018 we already had a large committee called *Comité de culture mathématique* at IHP. We enlarged it with volunteers who got interested in the project: researchers, teachers, science communicators, partner company representatives... This enabled us to gather a wide spectrum of expertise and a critical taskforce as well. We have continued to involve more people when we felt the need for it.

Smaller workgroups have been set up for each space, sometimes specifically for a given exhibit. At least two active researchers take part in each of those collaborative pieces of work. We have been used to this method for years for the design of smaller exhibitions and other outreach events. The institute is committed to maintaining this style of cooperation at least through the opening of The Maison Poincaré.

Table 2 *People figures*

1	museographer
1	scenographer
1	graphic designer
56	researchers
10	teachers
8	science communicators
3	deeptech company representatives
6	partner company representatives
5000	expected visitors per year
600	expected high-school classes per year
6	staff

Planned visitor experience

The permanent exhibition has been devised to offer a unique experience for visitors. It will occupy the whole ground floor with no predefined visit route. Instead visitors will discover its various spaces characterized by an action verb. In mere alphabet order they read: becoming; breathing; connecting; inventing; modelling; sharing; visualizing.

These action verbs are truly the skeleton of the museography program, intended to reveal various facets of what it means to practice mathematics. They have been chosen consistently with the layout of the premises and their historical significance, as it is shortly described in § **Guided tour of the premises** (page 7). They will be highlighted on suspended, transparent signs in French as summarized in Table 3 below. All other signs and panels will be translated into English so that foreign visitors can also enjoy visiting.

Table 3 *Spaces and verbs correspondence*

Foyer	CONNECTER	Connecting
Gallery	MODÉLISER	Modelling
Lecture hall	INVENTER	Inventing
Tea room	PARTAGER	Sharing
Perrin's office	DEVENIR	Becoming
Alice's room	VISUALISER	Visualizing
Garden	RESPIRER	Breathing

The exhibition will involve a great variety of museographic devices and appealing formats, ranging from hands-on displays, text panels, storytelling, portraits and videos to 3D printed objects, interactive screens, augmented reality and artwork. It will also include part of the institute's heritage collections, mathematical models (Villani and Uzan, *Objets mathématiques* 2017) and calculating machines.

We cannot describe every feature of the exhibition here. We have chosen to focus on a few of them that are quite representative of the spirit of the museography program.

Focus on low tech exhibits

Map of mathematics – connecting different fields



Picture 4 Artist view of foyer, with map of mathematics on the right wall. ©Atelier Novembre and Du&Ma

One of our low tech exhibits aims showing that mathematics is very diverse, with many fields that are interconnected to each other. It consists of a map surrounded by a certain number of more or less common objects that can be linked to mathematics. The map is a little bit like a metro map, with metro lines serving as metaphors for wide fields such as analysis or geometry and metro stations representing more specialized domains such as calculus of variations or differential geometry.

The public will have text panels to read that explain links of the reproduced objects (e.g. credit card, horse saddle, roulette, smartphone, etc.) with those domains. For those visiting on a guided tour (see § Individual vs guided tours page 19 for more details on tours) our science communicators will have the possibility to connect those objects physically to one or more 'metro line' thanks to elastic strings, and tell more about those connections.

The hands-on available in the middle of this space will have to do with several of the highlighted domains.

Coupled pendulums – illustrating solitons

Another low tech but nevertheless sophisticated exhibit is intended to display the concept of nonlinear wave. It will be made of a series of coupled pendulums on which the public will be

able to launch various kinds of waves. This is a mechanical model for observing the solitary waves that are otherwise ubiquitous in several domains of physics. We think that this is a great topic for our science communicators to talk about many applications of mathematics.

This `soliton' exhibit will be part of the gallery on the theme of modelling, which will offer many other devices for the public to explore.

Data separation – the basics of artificial intelligence

Also in the modelling gallery will be an exhibit representing what is known as the perceptron, a basic ingredient in artificial intelligence algorithms. The device will illustrate how some data can be classified in a binary manner, and separated by a simple surface. As can be seen on Picture 5, the classified data will be physicalized by small coloured balls – here blue or red – in 3D. The public will be able to walk around the exhibit and see those blue and red balls either apparently mixed altogether or, if they choose the good observation point, well separated by a plane.



Picture 5 Artist view of the gallery. ©Atelier Novembre and Du&Ma

Some explanation will be given on the text panel. This exhibit will be a good introduction to the Holo-Math (see Holo-Math – experiencing Brownian motion) episode on artificial intelligence, which is to be developed after the one on Brownian motion.

Researchers' experience narrative

In the space devoted to the theme of sharing, one of the exhibits will consist of a narrative that the public will be able to listen to under a sound shower while leafing through a book. This is not completely low tech since an RFID tag will turn the audio on and off.

Researchers will have told a writer how they live their academic life and how they come up with new ideas and make discoveries possibly in unexpected situations. The overall story will have been written and illustrated by professionals, and the text read and recorded by an actor.

Videos on various forms of engagement

Also not completely low tech will be videos presented in Perrin's former office, on the theme of becoming. They will be short documentary films on people who have been recognized for their engagement for mathematics in the society. They will be screened on either side of the chimney. As everywhere in the museum there will be a balance between men and women.

Focus on high tech exhibits

Interactive map – maths around the world at different ages

The chalkboard of the tea room can go up and be hidden in the casing above it. It thus releases a free wall in the rear. On this wall will be projected a map on which visitors will be invited to navigate through a remote panel. This map will aim at showing documents and other visual pieces of mathematics around the world. A cursor will also allow them to navigate in time.

This interactive map is a modestly technical exhibit that will tell and showcase how mathematics appeared and have been circulating and developing up to the most recent times. The specific contents will be worked out so as to be diverse, surprising and illuminating. Several of them will echo the other exhibits available in the room, in particular the device showing and whispering formulas, and the showcase dedicated to the connections between art and mathematics.

Image processing – beyond Fourier transform

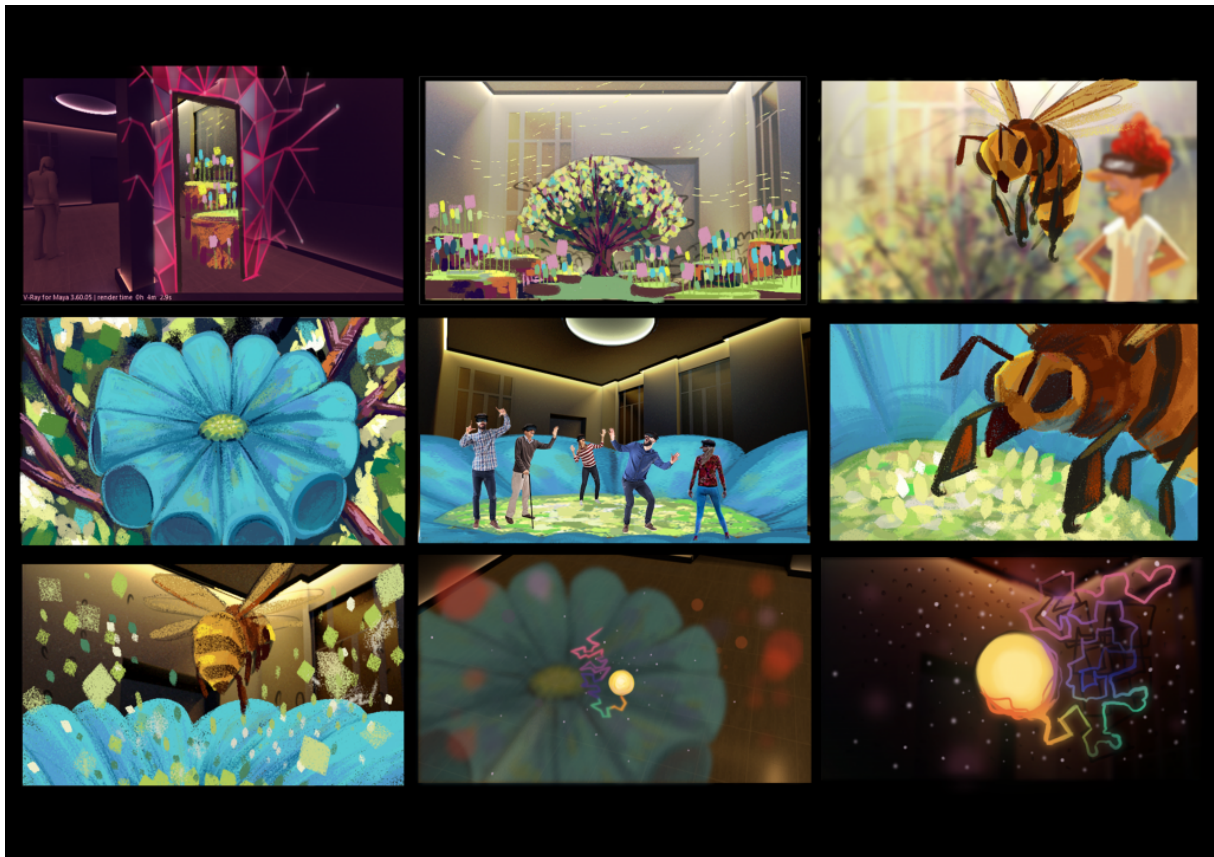
In the area dedicated to modelling, an electronic exhibit will enable visitors to apprehend what image processing means. They will have the possibility of compressing their own digital image, with a slider allowing them to choose the compression rate, according to two main processes, namely the Fourier transform and a wavelet transform. They will be invited to observe on two separate screens the advantages of the latter over the former. Some complementary explanation will be given on text panels.

Holo-Math – experiencing Brownian motion

The Holo-Math project is undoubtedly the most innovative one to be presented in the permanent exhibition. Following an original idea of Villani, it consists in using mixed reality to enable the public to use their own bodies to experiment with abstract concepts. Up to our knowledge this is a completely new way of addressing mathematics communication.

The main features of the Holo-Math experience will be the immersion in an animated 3D virtual universe without losing visual connection with the physical environment, and the possibility of interacting both with this universe and with the other people around. This is

what mixed reality headsets make possible. Another important feature is the crucial role of the science communicator who leads the experience.



Picture 6 Artist view of the Holo-Math episode on brownian motion. © ?

The proof of concept was made in 2017, and a first 25-minutes episode is about to be achieved. It deals with the Brownian motion, which is both a physical phenomenon²³ and a profound mathematical concept involved in the modern theory of probability and various applications.

This has demanded a tremendous amount of creative development. Given its huge cost, we are now seeking new resources to develop an episode on artificial intelligence.

Individual vs guided tours

We plan to offer four ways of visiting the permanent exhibition. Individuals will be allowed to enter and visit on their own for free. Otherwise, there will be focused guided tours, fully guided tours, and private tours.

Focused guided tours will consist of a 20-minutes exchange with a science communicator. They will enable for example the visitors to go deeper in a specific scientific question or

²³ A phenomenon that was used by Perrin to demonstrate the very existence of atoms, which earned him the Nobel prize.

challenge, or discover the life of a famous mathematician. The precise format of those visits is not defined yet. It is part of our job in the upcoming months to come up with a relevant offer.

Fully guided tours will be intended for groups, mainly school classes or group of teachers preparing a class visit. Private tours will be organised on demand, as has been repeatedly requested by our financial partners.

In order to optimize attendance and facilitate financial management, there will be no entrance fee. Only guided tours will be charged, and this will be done prior to visits.

Supplementary material

We have not defined yet the range of supplementary material but this will certainly include booklets made available from the shop, and detailed content on a dedicated website. We are also working with existing websites like Images des mathématiques²⁴ to offer various resources online.

Outreach activities

When the Maison Poincaré opens we will be ready to offer a diverse program of outreach events and activities to complement the permanent exhibition. Indeed, we have acquired a wide experience in this matter since 2016. We are going to keep up the momentum, and continue to experiment with various forms of science communication inside and outside the walls. We pay a lot of attention to the public feedback in order to improve our offerings regarding mathematics popularization.

Researchers

We organize public lectures by researchers who are staying at IHP, intended for schoolchildren and students but also for the general public. One difficulty is that a majority of visiting researchers are foreigners who can deliver lectures in English but not in French, whereas the targeted audience is not comfortable with attending a conference in English. This situation is improving given the number of incentives to promote English learning in the population.

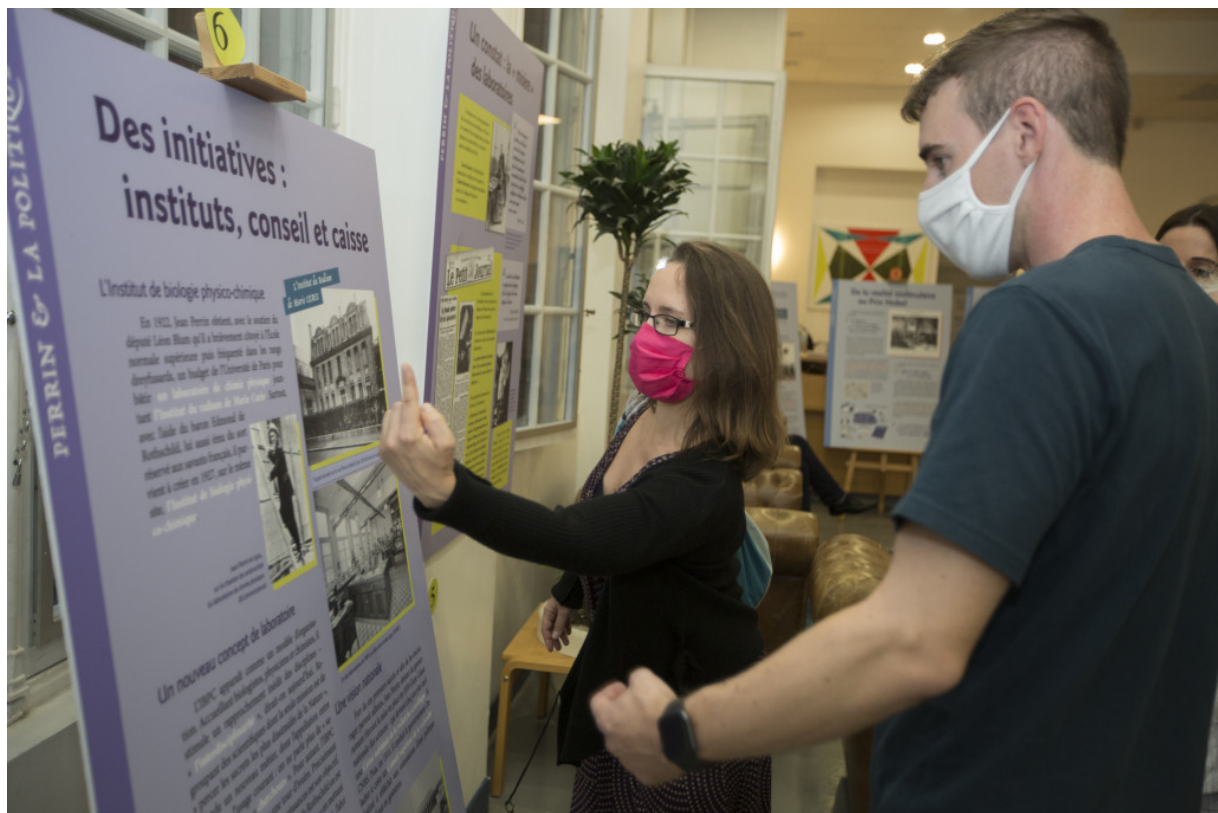
During the 2020 health crisis, we experimented for the first time with the organization of a webinar. We had invited a panel of researchers on site, we had a remote audience who could listen to them live through our brand new video broadcasting and recording system, and we enabled a conversation between researchers and the public through a chat managed by our animators. The feedback has been very positive and we are going to follow it up in 2021 with more content in this style.

²⁴ <http://images.math.cnrs.fr/>

We also have a partnership with Images des mathématiques²⁴, a website dedicated to the popularization of mathematics by researchers. We actually contribute with interviews of our visiting researchers, who thus introduce the readership to current research topics. In 2021, we will thus talk about evolution, phylogeny and ecology, gravitational waves, topology and cryptography.

Exhibitions

Over the years the IHP team together with their scientific network have designed a number of temporary exhibitions, most of them being available for loan to other institutions. These include exhibitions with a historical flavour in honour of past mathematicians²⁵ on the occasion of anniversaries, which we designed more for an informed public.



Picture 7 Exhibition on Jean Perrin, IHP library in September 2020. © Camille Cier

For the last couple of years, we have developed partnerships with MMI and Fermat Science to develop joint exhibitions that are more aimed at younger generations, in order to encourage them engage in STEM. For instance, we designed an exhibition on surfaces that was shown for one school year at Musée des arts et métiers and then at MMI. An exhibition on randomness was designed and shown at MMI. Similarly, there is an exhibition on artificial intelligence (AI) in preparation at Fermat Science. Both will be shown later in the Maison Poincaré.

²⁵ Maurice Audin, Gaston Darboux, Albert Einstein, Joseph Fourier, Évariste Galois, Sophie Germain, Joseph-Louis Lagrange, Jean Perrin, Henri Poincaré, Claude Shannon, Alan Turing.

Films

In the same spirit IHP has produced several documentary films that meet cinema standards, in complement with an exhibition save for the last, most original film. The first ones were dedicated to a scientist (Einstein, Lagrange, Shannon) and some of his achievements (general relativity, information theory, rational mechanics). The last two films are more art-oriented. One is about a math enthusiast who carves surfaces on copper, Patrice Jeener. The other, *Man Ray and the Shakespearean equations* plays with various views of the mathematical models pertaining to the institute that inspired the surrealist artist Man Ray. Two new films are in preparation, one in connection with a thematic research program and one about some societal issues linked with the use and misuse of mathematics.

Like for the exhibitions, we are happy to circulate documentary films as much as possible. There are DVDs that can be borrowed from our library, and screenings in remote institutions can be organized on demand, even abroad since the films are subtitled at least in English and can easily be subtitled in any other language.

Still in connection with the world of cinema, the institute has run a film club since 2014 at a nearby, legendary movie theatre nowadays called the *Grand Action*. Each session consists of the screening of a movie linked near or far to science followed by a recorded exchange²⁶ between the viewers and our invitees, who are generally researchers or film professionals.

Jams

In our desire to reach young and non-scientist people, we have also experienced innovative formats. The most innovative one was set up in 2019 together with the learned societies hosted in the building. After its big success another one should have taken place in 2020 would the pandemic not have disrupted in-person activities. We called it a *Jam*²⁷. The idea is to bring together researchers with laymen. They would gather for two days at the institute to imagine and produce new forms of creative expression on a given scientific theme.

²⁶ Subsequently made available on the institute's YouTube channel.

²⁷ In English in the text.



Picture 8 Jam du chaos, Hermite lecture hall at IHP in October 2019. © Camille Cier

The 2019 theme was chaos. Our *Jam du chaos* brought together more than 50 participants from very different backgrounds, such as plastic artists, musicians, video artists, graphic designers, students, developers, scientists and science communicators. In 2021 the theme will be health, in partnership with INSERM²⁸. Due to precisely the health crisis we had to postpone the Jam itself, and we organized a blended event instead, with a panel on-site that was filmed and live broadcast and a chat on-line.

Podcasts

Furthermore, we launched in 2019 with a professional radio journalist a podcast series, with the idea of departing from traditional radio broadcasts even though we took inspiration from a few of them. We wanted to highlight the temperament and ideas of those who do contemporary mathematics irrespective of their being known by the public or having published popular books. All the more so if they were not and had not.

This monthly podcast series is called *L'Oreille mathématique*²⁹, which does not translate well to English. Each episode is about 30 minutes long and features a conversation between the journalist, an invited scientist and a science communicator. Having had very good feedback so far, we will carry on next year, still paying attention to the representation of women and to the diversity of profiles when choosing our guests.

²⁸ The national institute for health and medical research.

²⁹ <http://maison-poincare.fr/podcasts/>

Workshops

Finally, a forthcoming project, which was also postponed due to the health crisis, is a workshop at the crossroads of academic research and tech companies on the theme of artificial intelligence. This is a format that we plan to renew on different topics.

Assets

One of our main assets in building the Maison Poincaré is the experience described in §

Outreach activities (page 20). Fortunately, we can claim complementary assets that are as important. These have to do with the very identity of the institute, with leadership and management features, secured financing and strong partnerships.

Prestige

The Maison Poincaré is not to be created from scratch. It is being built within the Institut Henri Poincaré, a research institute that is already internationally recognized. This configuration facilitates the work for its visibility. Even though the institute's visibility has to be developed further towards the general public, it is really an asset for enhancing the dialogue between scientists and the society. Scientists are present within our walls. It is up to us to go and convince them to interact with visitors.

Team

Another asset not to be overlooked is the steering and management of the project. For several years now, the institute's strategy has integrated this mission of disseminating science to society. As mathematicians and physicists the past and current directors and deputy directors have in common the knowledge and a real experience, even a personal one, of scientific communication. The operational team, IHP staff is wholly committed to the project, which clearly ensures desirable continuity and stability.

In addition, there are numerous skills at stake in the project team, namely, architecture, engineering, museography, scenography, audio-visual competence, digital skills, iconography and documentary research, project management, marketing, communication, financial management, partnerships and networking. We can rely on them to respond to basically any emerging problem.

Out of the nearly 25 people working at the institute, six ones are thoroughly involved in science communication missions. For six years since the project launch, we have learnt to work in a very collaborative way in order to create so many, very different from each other science communication activities. In particular, the IHP library has played an important role in the development in outreach activities, by contributing to and hosting if not steering exhibitions, by restoring and displaying the mathematical models, and by developing a documentary collection intended for a wide readership on science and its applications.

Support

We can also rely on, and are grateful to our funders for their continued support every year. Sorbonne Université and the CNRS follow very closely the progress of the Maison Poincaré. They are both proactive, and they have remarkably listened to our development needs. Our other public partners³⁰, the IHP endowment fund, patrons and partner companies and foundations are also powerful allies. They provide us with valuable advice on financing, networks and expertise as regards human resources, business model, marketing, strategy, media.

For each of our outreach projects like documentary films, exhibitions, augmented reality developments, book publishing, we have been assisted by service providers and professionals who excel in their fields.

Partnerships

In recent years, we have developed links and fruitful partnerships with inspiring scientific and cultural organizations. This includes neighbouring ones like the *musée Curie*, the *Panthéon* and *ESPGG*, other Paris museums like the *Musée des arts et métiers*, *Palais de la découverte*, *Musée du 11 Conti* (Monnaie de Paris), *Musée de l'Homme*, *Musée Guimet*, the movie theatre *Grand Action*, art schools (*École Boule*, *École nationale supérieure des arts décoratifs*), and *MMI* and *Fermat Science* elsewhere in France.

Furthermore, we have been working with many not-for-profit associations that are engaged in mathematics communication, in particular those which are hosted at IHP. We are also in close contact with *Les Maths en Scène*³¹, *Science Ouverte*³², which works at popularizing science in high schools from disadvantaged areas, and the *Institut Télémaque*³³, which offers support to students of modest origin and helps them to gain confidence in their training path, in particular by having them sponsored by companies.

Challenges

We are two years away from the opening and we still have many challenges to meet.

Fundraising

So that the Maison Poincaré can function properly, we must have a great fundraising strategy with companies and individuals. This implies expanding our network of companies by meeting

³⁰ The city of Paris, the Ile de France region and the French state.

³¹ <https://lesmathsencene.fr/>.

³² This name here does not refer to Open Science in the science publishing business. It stands for openness to all types of public. See <https://scienceouverte.fr/>.

³³ <https://www.institut-telemaque.org/>

people in the digital, finance, energy, etc., fields. The IHP endowment fund is in charge of carrying out this fundamental mission, which has unfortunately been jeopardized by the economic crisis induced by the pandemic. We must certainly engage even more in helping them to raise funds.

Another crucial item in the business model for the extended IHP and in particular the Maison Poincaré lies in getting revenues from the Perrin building itself. We are convinced, and this has been confirmed by our network that given its location and beauty³⁴, there will be some demand to rent seminar rooms, salons, and even the garden of the building. Nevertheless, we still have to create a credible offer to run efficiently the promotion of these premises and rent them profitably.

Inclusivity

It is highly desirable if not mandatory that our exhibitions and events be accessible to visitors with disabilities. Even though we are very much aware of this, and scenographers and graphic designers as well, it is far from being obvious how to adapt exhibits to all kinds of disability. We have been working with students and science communicators with disabilities as advisors, but there is still a lot of work to do.

Gender equality is also kind of a challenge in our projects. For instance, it is sometimes very hard to find female speakers for the film club or documentary films. We are also aware that gender equality has by far not been achieved in our temporary exhibition themes. This issue will be addressed in the upcoming programming. On the other hand, in the permanent exhibition we have chosen to balance the visibility of women with that of men despite their appalling underrepresentation in the STEM community. Even though it will satisfy many people, we know that we may face criticism for this choice, as is already the case regarding our use of inclusive writing in our communication.

Attractiveness

Dialogue between researchers and the public is another challenge. Indeed, our visiting researchers are on site but it is not clear whether they will be willing to interact with the public. The language barrier is one of the difficulties to cope with, since the French laymen are hardly comfortable with talking with strangers in English. We must find easy ways and original incentives to stimulate discussions and exchange, be it through organized or informal encounters. This mission will be part of the job of our permanent team of science communicators, provided that we can secure positions.

Last but not least, if our campus is attended by lots of scientific students and academics it is much less known by the public. So we must clearly change this and advertise our campus, the institute, our activities, the Maison Poincaré. The help of the city of Paris is going to be crucial in this matter.

³⁴We have not described the upper floors here but they will be spacious and gorgeous.

We will consider us successful only if junior and senior high-school students, in particular from disadvantaged areas, come in numbers to the Maison Poincaré. To achieve this goal, we must mobilize and involve teachers, teachers' associations, libraries, universities and school boards. We would consider as a success a minimum of 15 000 students (600 class groups) and 5 000 other visitors per year.

Conclusion

Of course the opening of the Maison Poincaré that we all look forward to will be a crucial step in the project, but definitely not the last one.

Meanwhile we will have offered virtual visits to our targeted audience and partners, and tested with teachers and their students a number of hands-on.

It is our intent to continue our collaborative design method and improve our offerings by taking into account feedback from our public on the long run.

We will also continue to share good practice and circulate our productions within our national network so that more people can benefit from them.

More generally, we have the ambition of becoming a source of inspiration regarding mathematical communication, in partnership with our national and international network.

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Links

Documentary films : <http://www.ihp.fr/fr/production-films>

Film club : <http://www.ihp.fr/fr/cine-club>

Exhibitions: <http://www.ihp.fr/fr/grand-public/expositions-originales>

Podcasts : <https://maison-des-maths.paris/podcasts/>

Interviews : <https://images.math.cnrs.fr/-L-institut-Henri-Poincare-IHP-.html>