ESPCI PARIS

EDUCATION SCIENCE INNOVATION

ANNUAL REPORT
2015-2016

PSL RESEARCH UNIVERSITY PARIS

MAIRIE DE PARIS

SINCE 1882,
ESPCI PARIS HAS BEEN TRAINING INNOVATION ENGINEERS WHO ARE READY TO INVENT THE FUTURE AND MEET THE CHALLENGES OF TOMORROW.

BOASTING **6 NOBLE PRIZES AND MORE THAN 522 PROFESSOR-RESEARCHERS** SPREAD ACROSS 9 JOINT RESEARCH UNITS, ESPCI CREATES INNOVATION BY ENCOURAGING AN **INTERDISCIPLINARY APPROACH** AND DIALOG BETWEEN BASIC AND APPLIED SCIENCES.

CONTENTS

MARIE-CHRISTINE LEMARDELEY
President of ESPCI Paris

JEAN-FRANÇOIS JOANNY
Director General of ESPCI Paris

JOINT INTERVIEW
OUR APPROACH IS NOVEL IN THE WORLD OF ENGINEERING SCHOOLS

ESPCI IS AN UNUSUAL EXAMPLE AMONG FRENCH ENGINEERING SCHOOLS.

JFJ: Indeed it is, and for several reasons. Our approach is novel in the world of engineering schools: teaching is done through research, and the school's curriculum and approach to research are based on interdisciplinary studies and innovation. Our teachers are all working researchers. Seventy percent of our students continue on to a PhD after their fourth year. Many of the researchers working in our laboratories no longer question whether they're physicists, chemists or biologists.

MCL: ESPCI also has deep roots in the heart of Paris. Montagne Sainte-Geneviève, located in the capital's very core, has historical ties to French research through institutions like the École Normale Supérieure and Institut Curie.

JFJ: The school plays a large role in that history, boasting six Nobel Prize winners, including Pierre and Marie Curie, and more recently Pierre-Gilles de Gennes and Georges Charpak. Our priority is to attract the best students and train engineers with a unique set of skills. We are constantly improving our pedagogical methods to support creativity and a culture of innovation. We also want to strengthen the school's position as a world-class research center in physics, chemistry and biology, by attracting the best French and international researchers, and by developing new fields of research. Naturally, we continue to innovate in promising research fields like microfluidics, wave physics for medical applications, biomedical engineering, materials studies, and more.

MCL: The school's international renown and visibility also fall within our priorities: we will continue to support research by and excellence within the teaching staff, notably within the framework of PSL Research University, the community of universities (ComUE) to which we belong. We will continue deploying our strategy of partnerships, dual diplomas and alliances with major universities in Brazil, China, North America, Israel and beyond.

THE SCHOOL DEFENDS A UNIQUE APPROACH TO TEACHING AND SCIENTIFIC RESEARCH. WHAT IS IT?

JFJ: Our goal is to train engineers capable of responding to the needs of a constantly changing society, and who will adapt to that society's evolution. The phrase "breaking down barriers" sums up the school's vision well: barriers between the scientific disciplines of physics, chemistry and biology, which continually influence one another; between teaching and research, which are closely connected; between the scientific and economic worlds (laboratories, start-ups and industry rub shoulders within our walls); and finally, between basic and applied research, which interact with and enrich one another.

MCL: The school has the advantage of being human-scale, and not only in terms of space. Student, doctoral candidates, professor-researchers, researchers and entrepreneurs constantly interact, engage in discussion, share their problems and seek solutions together. This positioning enables a singular approach to problems and rapid engagement with new fields of innovation.

WHAT IS DIFFERENT ABOUT THE "ESPCI METHOD"?

JFJ: We recruit motivated students at the highest level. Our unique pedagogical method relies on research-based learning, scientific excellence and prioritizing the experimental method. Our students spend more than half their time on practical work. This approach enables us to train professionals with a unique set of skills: engineers and researchers who are passionate, creative, capable of tackling problems in new ways, with a solid theoretical background and an equally firm grasp on society's challenges.

MCL: The school also imparts a strong culture of innovation, and its incubator hosts fourteen start-ups with roots in the school's laboratories or founded by ESPCI students.

WHAT VALUES DOES THE SCHOOL DEFEND?

JFJ: I'd like to emphasize four: scientific excellence, an openness to the economic and academic spheres, the freedom to be inventive, and creativity. Our researchers are free to choose their own research topics. The school supports them and provides them with the means to see their projects through to completion.

HOW DOES THE CITY OF PARIS SUPPORT ESPCI?

JFJ: The City of Paris is a very important support, and we work in close collaboration. This relationship contributes greatly to the flexibility and the reactivity of our education and research.

MCL: ESPCI Paris enjoys a freedom owed in part to its municipal support, the City of Paris, which provides the means necessary to maintaining excellence in teaching and research. We also position ourselves within the PSL Research University dynamic, its objective being to ensure the influence of Paris and its universities. This freedom, coupled with a flexible model, enables ESPCI Paris to remain firmly oriented towards research and start-up creation. ESPCI intends to be the spearhead of the City of Paris' attractiveness.

IS CAMPUS MODERNIZATION PART OF THIS STRATEGY?

JFJ: Indeed. Modernization begins late 2017 and should wrap up in 2022. This project is more than a "simple" modernization. Our support has made an unprecedented investment of 176 million euros for teaching and research facilities worthy of the school's ambitions, which will provide the school with fresh momentum.

4 CAMPUSES

32,600 M² DEDICATED TO TEACHING AND RESEARCH IN THE HEART OF PARIS

1 ESPCI PARIS
VAUQUELIN CAMPUS

Created: 1882
Excellence initiative: 8 of 9 joint research units are located on Vauquelin Campus
Surface area: 25,000 m²
Researchers: 393

2 LANGEVIN INSTITUTE
CUVIER CAMPUS

Created: 2009
Excellence initiative:
EQUIPEX – LABEX
Surface area: 2,200 m²
Researchers: 60

3 LANGEVIN INSTITUTE WAVE PHYSICS FOR MEDICINE AND BIOLOGY
MOREAU CAMPUS

Created: 2016
Excellence initiative:
ART INSERM
Surface area: 1,200 m²
Researchers: 49

4 PIERRE-GILLES DE GENNES INSTITUTE
CALVIN CAMPUS

Created: 2015
Excellence initiative:
Carnot Tremplin Label
Surface area: 4,200 m²
Researchers: 20

6
ESPCI NOBEL PRIZE WINNERS (PIERRE AND MARIE CURIE, FRÉDÉRIC JOLIOT-CURIE, PIERRE-GILLES DE GENNES AND GEORGES CHARPAK)

≃ 500
SCIENTIFIC PAPERS PUBLISHED EACH YEAR, OR MORE THAN ONE EACH DAY

1
PATENT PER WEEK

3
START-UPS CREATED EACH YEAR

522
RESEARCHERS, TEACHER-RESEARCHERS, POST-DOCTORAL STUDENTS AND DOCTORAL CANDIDATES

90
STUDENT-ENGINEERS IN EACH GRADUATING CLASS

2ND
BEST ENGINEERING SCHOOL IN THE SHANGHAI RANKING

70%
OF STUDENT-ENGINEERS CONTINUE WITH A PHD

6 NOBEL PRIZES
EXCELLENCE, OPEN-MINDEDNESS AND SCIENTIFIC FREEDOM

- **1882** — SCHOOL FOUNDED
- **1898** — **PIERRE AND MARIE CURIE DISCOVER RADIUM** — NOBEL PRIZE IN 1903
- **1907** — Georges Urbain discovers Lutetium
- **1910** — **MARIE CURIE ISOLATES RADIUM** — NOBEL PRIZE IN 1911
- **1914** — Paul Langevin invents sonar
- **1920** — Fernand Holweck describes continuity between ultraviolet rays and x-rays
- **1928** — Paul Dubois invents the oscillograph, precusor to the "black box"
- **1934** — **FRÉDÉRIC AND IRÈNE JOLIOT-CURIE DISCOVER ARTIFICIAL RADIATION** — NOBEL PRIZE IN 1935
- **1939** — Charles Dufraisse discovers rubrene
- **1962** — Philippe Dreyfus invents the term "informatique" (information technology)
- **1980** — Claude Boccara discovers unique measurement methods for use in optics and imaging
- **1990** — Time reversal of acoustic waves by Mathias Fink
- **1991** — **PIERRE-GILLES DE GENNES FOR HIS WORK ON POLYMERS, LIQUID CRYSTALS, SOFT MATTER** — NOBEL PRIZE IN 1991
- **1992** — **GEORGES CHARPAK FOR THE MULTIWIRE CHAMBER** — NOBEL PRIZE IN 1992
- **1994** — Neurobiology laboratory created / Science Center opens
- **1999** — ParisTech network launched; ESPCI is a founding member
- **2009** — Langevin Institute Waves and Images founded
- **2010** — ESPCI Paris Georges Charpak endowment fund created
- **2011** — PSL Research University Paris created
- **2015** — Pierre-Gilles de Gennes Institute for Microfluidics created / ESPCI ParisTech becomes ESPCI Paris
- **2016** — IMAP laboratory created with ENS and CNRS / First accelerator of technological research (ART) created Inserm-Biomedical Ultrasounds
- **2018** — Campus remodel begins
- **2023** — ESPCI RENOVATED

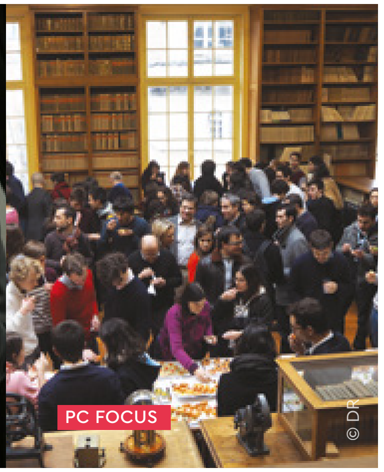
HIGHLIGHTS

ESPCI PARIS HAS REACHED A TURNING POINT IN ITS ILLUSTRIOUS HISTORY.
THANKS TO INVESTMENT BY ITS STEWARD, THE CITY OF PARIS,
THE SCHOOL IS REINVENTING ITSELF AFTER TAKING TIME TO REFLECT
ON ITS POSITIONING, IDENTITY AND INFLUENCE.
HERE ARE SOME HIGHLIGHTS FROM 2015 AND 2016.

LUDWIK LEIBLER © DR


PARTNERSHIP WITH THE INSTITUT PASTEUR © DR


THE MAGIC OF WAVES © DR


PC FOCUS © DR


THE 130TH CLASS GRADUATES © W. Parra

INAUGURATION OF IPGG AND ESPCI PARIS INCUBATOR © stefania iemmi

2015

LEADERSHIP REORGANIZATION

In 2015, Véronique Bellosta became Dean of Academic Programs and Rémi Carminati became Dean of Research. The previous year, Jean-François Joanny succeeded Jacques Prost as the institution's Director General.

134TH CLASS: A YEAR OF EQUALITY

Gender parity was achieved for the first time in 2015, with 45 women and 45 men in the 134th class, which contradicted the usual figures, though ESPCI attracts an increasing number of women students seeking an excellent scientific program. Marie Curie, the first woman to win a Nobel Prize and the only woman to have won two, symbolizes this gender parity.

STRATEGIC PARTNERSHIP WITH THE INSTITUT PASTEUR

On September 16, 2015, ESPCI and the Institut Pasteur signed a scientific partnership in the field of biology with the objectives of facilitating mobility for researchers and the exchange of knowledge and technology in leading-edge projects. The two institutions had already begun collaborating on droplet-based microfluidics studies for the selection of new medicines and vaccines; super-resolution structured illumination microscopy; and field-based Ebola diagnosis using paper microfludics.

LUDWIK LEIBLER ELECTED TO THE ACADÉMIE DES SCIENCES AND AWARDED THE 2015 EUROPEAN INVENTOR AWARD

Ludwik Leibler, Research Director at CNRS, director of the Soft Matter and Chemistry laboratory at ESPCI and ESPCI Paris Distinguished Professor, was elected to the Chemistry department of the division of chemical, biological and medical sciences and their applications at the Académie des Sciences. He was a recipient of the European Inventor Award for his discovery of vitrimers, a new class of organic materials, which he introduced with his team. Reparable and recyclable, they, like glass, can be shaped and reshaped infinitely, while remaining insoluble, light and resistant.

TWO YOUNG WOMEN RESEARCHERS RECOGNIZED

On September 30, 2015, two young researchers from ESPCI Paris were chosen from among 820 candidates to receive the L'Oréal-UNESCO For Women in Science Award. Marine Bézagu and Laura Magro both work in the field of biomedicine. Bézagu experimented with a new therapeutic approach to fight cancer using micro-droplets. Magro developed a paper-based device to be used in medical laboratories for faster and more efficient diagnosis.

THE MAGIC OF WAVES

Held on November 5 and 6 by the Langevin Institute in honor of Mathias Fink, this two-day colloquium provided an occasion to discover the latest advances in wave physics.

PIC: A LABORATORY WHERE ACADEMIC RESEARCHERS AND INDUSTRY MEET

The PIC (Physical Chemistry of Complex Interfaces) laboratory, which connects Total with researchers at the SIMM Laboratory (ESPCI-CNRS-UPMC) was inaugurated on December 15 in Lacq, situated between Pau and Orthez at the foot of the Pyrenees Mountains. The selected scientific themes concerned physicochemical phenomena that occur within petroleum-water-solid interfaces, responsible for many of the problems encountered in the production of hydrocarbons.

2016

TOTAL AND ESPCI PARIS RENEW THE "SCIENCE AND INNOVATION FOR THE ENERGY OF TOMORROW" CHAIR

On January 14, Total and ESPCI Paris renewed their shared desire to collaborate by re-signing the Science and Innovation for the Energy of Tomorrow chair several weeks after the PIC laboratory opened in Lacq.

THE 130TH CLASS GRADUATES

No fewer than 500 people gathered Friday, February 19 in the chambers of Paris City Hall to witness the graduation ceremony of the 130th graduating class. It was an exciting evening for the young engineers trained by the school.

PC-FOCUS 2016

The PC-Focus day took place on February 18. Each year, this large internal event gives those involved with the school a chance to get to know each other better, and exchange and share ideas.

INAUGURATION OF IPGG AND ESPCI PARIS INCUBATOR

On March 14, new facilities for the Institut Pierre-Gilles de Gennes (IPGG) for microfluidics, of which ESPCI is a key partner, were inaugurated in the presence of French President François Hollande, and the Mayor of Paris, Anne Hidalgo. This new world-class scientific hub includes 4,000 m² of new space dedicated to basic research and innovation. The IPGG also houses PC'up, ESPCI's incubator and host to 16 start-ups, confirming the school's deeply-rooted tradition of entrepreneurship.

A NEW LOGO FOR A NEW NAME

ESPCI ParisTech became ESPCI Paris, a means of more formally rooting the school within Paris' administrative supervision and in PSL Research University. As for the school's new logo, unveiled on June 9, it responded to three challenges: affirm the school's modern character without renouncing its prestigious history via a coat of arms depicting the school's nickname: PC (physics, chemistry); improve the school's international recognition with the motto "Education Science Innovation," legible in both French and English; and affirm its affiliation to Paris.

ESPCI PARIS GALA
© DR

INTERNATIONAL PHYSICISTS' TOURNAMENT
© J.F. Dars

ADOCIA MENTORS THE 135TH ESPCI GRADUATING CLASS
© Contextes

CHARLÈNE GAYRARD AND PASCALINE HAYOUN RECOGNIZED BY L'ORÉAL
© DR

CARNOT SPRINGBOARD LABEL

On July 6, 2016, the Institut Pierre-Gilles de Gennes (IPGG) for microfluidics received the Carnot Tremplin Label, which strives to support the development of research partnerships and technology transfer between public research and companies through contract research.

RECIPIENTS OF THE EUROPEAN RESEARCH COUNCIL (ERC) GRANTS

Two ESPCI researchers were recognized by the ERC for their work: Costantino Creton from the SIMM Laboratory received one of only two French ERC Advanced Grants awarded in chemistry for an interdisciplinary project on fracture mechanisms in soft materials. Anke Lindner from the PMMH Laboratory won a ERC Consolidator Grant for a project on complex suspension dynamics.

ESPCI PARIS GALA

Each year in June, students, engineer-graduates, researchers, administrative personnel,doctoral candidates and industry representatives gather for the ESPCI gala, an entirely student-organized event. In 2016, it was held at the Chalet de la Porte Jaune in Vincennes—a unique setting for an exceptional evening.

INTERNATIONAL PHYSICISTS' TOURNAMENT

More than 100 physics students from fourteen countries attempted to solve roughly twenty physics problems during the eighth edition of the International Physicists' Tournament. Over the course of a week, from April 17 to 23, 2016, students battled it out in English during public debates held at ESPCI.

ADOCIA MENTORS THE 135TH ESPCI GRADUATING CLASS

Historically, the class mentor has been a global leader, but this has evolved in recent years, with Withings in 2014 and Adocia in 2016, both reflecting a new image of industry composed of human-scale companies with a strong innovative portfolio. In 2016, Adocia mentored the students of ESPCI's 135th graduating class. A family company founded in 2005, Adocia is a biotechnology company specialized in the development and formulation of proteins, notably those used in treating diabetes.

INAUGURATION OF NEW FACILITIES AT THE WAVE PHYSICS FOR MEDICINE AND BIOLOGY AT LANGEVIN INSTITUTE

On October 26, 2016, in the presence of Thierry Mandon, Secretary of State for Higher Education and Research, ESPCI Paris and Inserm inaugurated the Technological Research Accelerator (ART) Inserm - Biomedical Ultrasounds and new facilities for the Wave Physics for Medicine and Biology team at Langevin Institute. Directed by Mickaël Tanter, this research team has 50 members.

TWO YOUNG WOMEN RESEARCHERS RECOGNIZED BY L'ORÉAL

In 2016, two ESPCI Paris graduates landed this prestigious fellowship and placed among 30 winners: Pascaline Hayoun, carrying out a CIFRE PhD with the Science and Engineering of Soft Matter laboratory at ESPCI Paris and Saint-Gobain; and Charlène Gayrard, carrying out a PhD at Institut Jacques Monod (CNRS, Paris Diderot University). Pascaline studies fluid systems, in particular how fluids flow through plastic tubes. The possible applications are numerous, notably for infusion bags and cell culture environments. Charlène investigates the mechanical forces exerted on living cells during their lifespans. Her work shed light on the role played by two proteins, whose malfunction is involved in a number of cancers.

ESPCI PARIS DISTINGUISHED PROFESSOR

Mickaël Tanter (Inserm), Ludwig Leibler (CNRS) and David Quéré (CNRS) were the first to hold the title ESPCI Paris Distinguished Professor. They were awarded this title on November 29, 2016, in recognition of their pioneering contribution to French and international research. The title highlights three brilliant careers that combine basic science and direct applications for society, in the field of medical imaging and new materials.

"On June 9, 2016, the school that produces Nobel Prize winners got a makeover. ESPCI Paris adopted a new image, one in line with the establishment's ambitious strategy: a logo at once classic and modern that echoes the universal conventions of leading international universities."

THE NEW ESPCI PARIS
PLANNED FOR 2023

Created in 1882 by the City of Paris, enlarged in the 1930s and again in the 1990s, ESPCI's historical location called for a complete remodel. The City of Paris decided to invest 176 million euros in this unprecedented project.

Spurred on by the City of Paris, ESPCI began a large development project for teaching and research facilities slated for completion in 2023. The school's objective is to become the international reference for research and training centers in the fields of science, technology and innovation.

Architect Anne Démians, winner of the international competition spearheaded by the City of Paris, proposed a design in which new construction does not alter the school's historical spirit. The goal is to modernize the school by tearing down the succession of buildings juxtaposed and superimposed over the years since its foundation in 1882. The City of Paris' 176 million investment will give the school a campus worthy of its scientific excellence.


© D.A Architectes

"Return coherence to a site imbued with prestigious history."

HISTORIC RESTRUCTURING

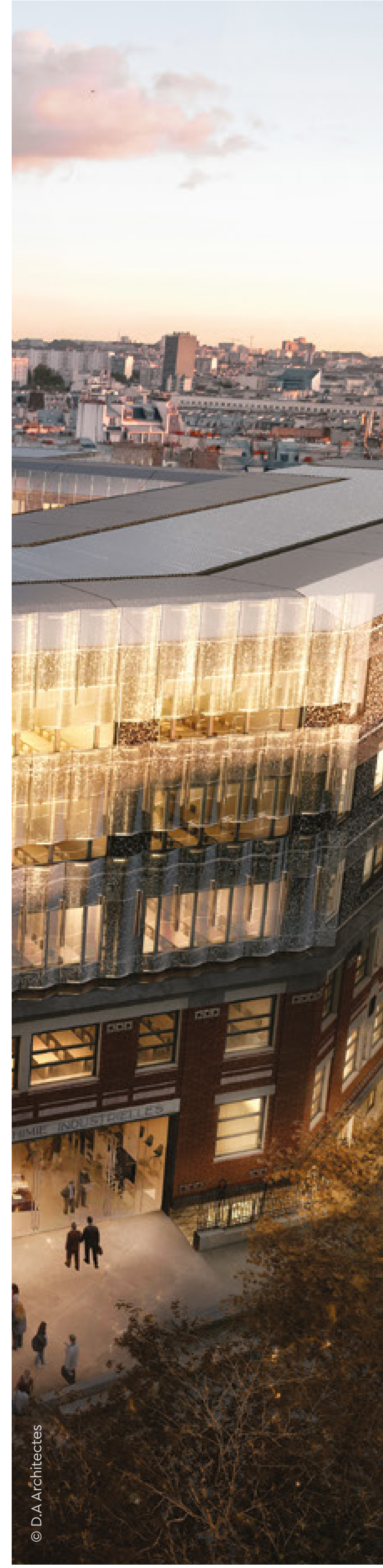
The days of multiple small buildings are over: the structure's identity will be asserted through an injection of coherence and homogeneity. Adapted to ESPCI's unique educational model, this project is the opportunity to give it new scope. This idea lies at the very core of the restructuring: revive the school's attractiveness while preserving the existing building's historic and unusual character. To this end, the beautiful street-facing Art Deco facade will be preserved. The vertical enlargement and the flooring will be demolished and the buildings enlarged. They will accommodate areas for innovative research, teaching zones and amphitheaters. A central hub will connect the different spaces to facilitate exchanges between all ESPCI users (teachers, researchers, students, visitors...).

AN OPEN PARISIAN CAMPUS...

The new building will be even better connected and open to neighboring PSL members located on the Montagne Sainte-Geneviève. The remodeling project is based on restructuring the site following a spiral configuration, moving from the exterior towards the center of the building cluster. The building works will enable transfer of the entrance to Place Alfred Kastler, ensuring an even greater connection with the city.

...AND THE CUTTING EDGE OF MODERNITY

Designed with the needs of researchers and student-engineers in mind, the structure is intended to evolve with and adapt to science and teaching. Increasing from 29,000 m² to 34,500 m² (of which 25,000 m² are dedicated to research laboratories and 3,800 m² to teaching facilities), the surface area allotted to ESPCI will be modernized.


© D.A Architectes

LATE 2017
WORK BEGINS

34,500 M²
OF FLOORSPACE

3,900 M²
OF PROTECTED GREEN SPACES RESTORED

€176 M
TOTAL OPERATIONAL COST (VAT)

2020
FIRST PHASE TO BE COMPLETED

2023
ALL WORK TO BE COMPLETED

CONSTRUCTION SCHEDULE

Early 2017
Building permit request
Late 2017
Worksite set-up
2018-2020
Demolishment of 9 buildings and construction of central building (phase 1 - central building)
2020-2023
Renovation of surrounding buildings and connections (phase 2 - surrounding buildings)

THREE QUESTIONS FOR ANNE DÉMIANS, architect

Anne Démians, tell us about yourself.

After studying at the National School of Architecture in Versailles, I started my first architecture agency in 1995. In 2005, I radically revised the field of application and scope of my goals in order to give myself more freedom. Since then, I've directed an agency made up of thirty architects and engineers under the name Architectures Anne Démians. I've won several bids, including a freight station in Orly, several housing projects, the redevelopment of Guyancourt's hospitality and tourism vocational school, and the Douai city courthouse. In late 2007, I gained recognition through my work on high-rises in Paris, notably the Masséna-Bruneseau neighborhood in the 13th arrondissement.

What was challenging about the ESPCI project?

It's always difficult to announce that an existing building must be destroyed or replaced by a new construction. In the collective unconscious, modifying a building's structure all too often implies altering its identity. In this case, the idea was to bring particular attention to what exists to draw out the school's very essence and in doing so, deliver a "custom" creation in concert with the desired goal of architectural synergy.

How did you go about doing this?

An extraordinary location and character give this project a true identity, one of modernity in the heart of Paris. Nevertheless, things were clear from the start: the site lacked coherence. It needed homogeneity, but above all, the accumulation of small buildings had to go. This inspired the proposed spiral structure which returns the entrance to Place Alfred-Kastler. In reimagining the ESPCI spaces, my intention was above all to foster meeting spaces, an essential element the school lacked until now.

ESPCI ALUMNI
A NEW NAME FOR PAST STUDENTS

Unite, promote and support. With this triple objective in mind, ESPCI Alumni experienced a year full of changes: a new name, the creation of a Twitter account, a new partnership for employment...

Two years after ESPCI was founded, the Association of ESPCI Engineers (AIE) was formed. This long-established association has three main goals: unite the greatest number of former students as possible; promote the profession of ESPCI engineer and the school's diploma; support the school's development. Regarding this final point, discussions were initiated with the school's administration based on feedback from alumni collected through surveys concerning changes to the school's name carried out in 2007 and 2015. The association actively participated in reworking the school's positioning and visual identity, which now includes the brand name ESPCI Paris. As for the AIE, it is now known as ESPCI Alumni, a much clearer and more recognizable name in line with the school's reputation.

CONNECT AND PROMOTE *VIA* SOCIAL MEDIA

The association seeks to grow its presence on social media in order to connect the school's 3,000 former students and promote Alumni successes and achievements, as well to increase the school's visibility. All year long, members of the association manage the Twitter account to reach engineers around the world. Created in 2012, @espci_alumni now counts more than 5,900 tweets and boasts more than 2,800 followers, placing it fourth among Twitter accounts representing *grandes écoles* alumni, just behind HEC, ESSEC and Sciences Po. ESPCI Alumni also broadcasts 250 videos on YouTube, Vimeo and Dailymotion.

HELP STUDENT-ENGINEERS FIND INDUSTRY EMPLOYMENT

Since its creation, the association has not only provided financial aid to student-engineers, but has also helped steer them toward the industrial sector where they will find work. In 2015, loans totaling 20,000 euros were granted to nine students. Since 2010, ESPCI Alumni has also awarded merit scholarships to student-engineers who choose to continue with a second year of a science-oriented masters program. Out of twenty-five applicants (a number that increases each year), nine candidates were retained, then four were awarded this 5,000-euro scholarship. Another, the prize for best industry internship, has been awarded since 2006.

"In 2016, Sylvain Gilat, an engineer from the school's 107th graduating class, was elected Alumni president."

Regarding projects favoring employment and careers, all alumni have exclusive access to JobTeaser.com, a partner that provides access to thousands of job offers, as well as internships and PhDs. Every year in June, the CV Book, which includes more than forty student resumes, is shared with recruitment agencies and major companies. The "Employment-Careers" section of the ESPCI Alumni site now includes offers from the ParisTech network and APEC, as well as a job interview simulator.

CREATE TIES TO INDUSTRY

The association also organizes themed evenings during which an industry figure is invited to address a current topic of interest to ESPCI engineers. After hearing from François Minster (Scientific Director at Total) and Agnès Paillard (president of the French National Intellectual Property Institute (INPI), in June 2015, the ESPCI Alumni evening welcomed Pierre Pringuet, Vice-President of Pernod Ricard's board of directors and President of the French Association of Private Businesses (AFEP), to speak on the theme "From engineer to CAC 40 boss." This wonderful gathering gave 100 attendees the chance to discuss with this reserved but prominent leader, who happens to be very fond of the school.

PSL RESEARCH UNIVERSITY
ESPCI PARIS: MEMBER OF A WORLD-RENOWN UNIVERSITY

ESPCI Paris is a founding member of PSL Research University. An international university located in the heart of Paris, PSL combines excellence and diversity to create interactions between every field of knowledge and creation in the arts, engineering, science, and humanities.

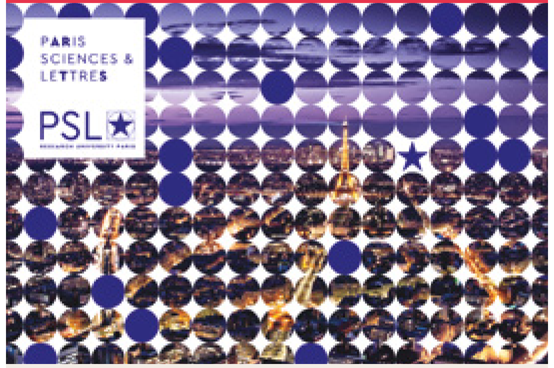
With 19,000 students and 5,000 professor-researchers, PSL is comparable to the world's major universities in that it favors capacity for action over sheer size.

The university—recipient of the Investments for the Future program—brings together 26 prestigious establishments committed to offering their communities unprecedented opportunities in the fields of training, research, value creation, and domestic and international industry and academic partnerships.

An incubator of 33 Nobel Prizes, 10 Fields Medals, 38 Césars and 71 Molières, PSL concentrates exceptional energy. Its academic community takes advantage of the potential offered by 178 laboratories to establish major structuring, innovative and radically interdisciplinary projects, which enrich its educational programs.

Selected for their talent and carefully guided, PSL students draw from this scientific and cultural environment the resources they need to develop their intellectual capacity, daring and creativity. Whether they become artists, entrepreneurs, researchers or leaders, they are aware of their social, individual and collective responsibilities; they are open to the opportunities a globalized world presents; and they are prepared for the major shifts taking place in today's professional context. Attentive to the choices of its students, PSL supports diversity within student backgrounds, regardless of social status, gender or geographic origins.

A major cultural and artistic center, PSL offers its community and a wider audience access to its many resources: conferences, debates, exhibitions, performances, concerts, and more. PSL builds strategic global partnerships with the world's major universities. Closely connected to the world of business, PSL contributes to transforming the results of research carried out within its establishments into true vectors of innovation and economic growth. Since its establishment five years ago, PSL has created 41 start-ups, filed more than 350 patents and signed more than 2,500 industry partnerships.



PSL MEMBER INSTITUTIONS

Chimie ParisTech, Collège de France, Conservatoire National Supérieur d'Art Dramatique, Conservatoire national supérieur de musique et de danse de Paris, École des Hautes Études en Sciences Sociales, École française d'Extrême-Orient, École nationale des chartes, École nationale supérieure des Arts Décoratifs, École nationale supérieure des Beaux-Arts, École normale supérieure, École Pratique des Hautes Études, ESPCI Paris, Fondation Pierre-Gilles de Gennes pour la recherche, IBPC-Fondation Edmond de Rothschild, Institut Curie, Institut Louis Bachelier, La Fémis, Lycée Henri IV, MINES ParisTech, l'Observatoire de Paris, Université Paris-Dauphine, Association Art et Recherche, CNRS, Inria, Inserm, Institut Pasteur.

ESPCI PARIS FUND
SUPPORTING EXCELLENCE

The ESPCI Paris Fund was created in December 2010 through a joint initiative by the school, the City of Paris and ESPCI Alumni. The goal: support the school's development and influence.

Student-engineers working on physics "team science projects" (PSE).

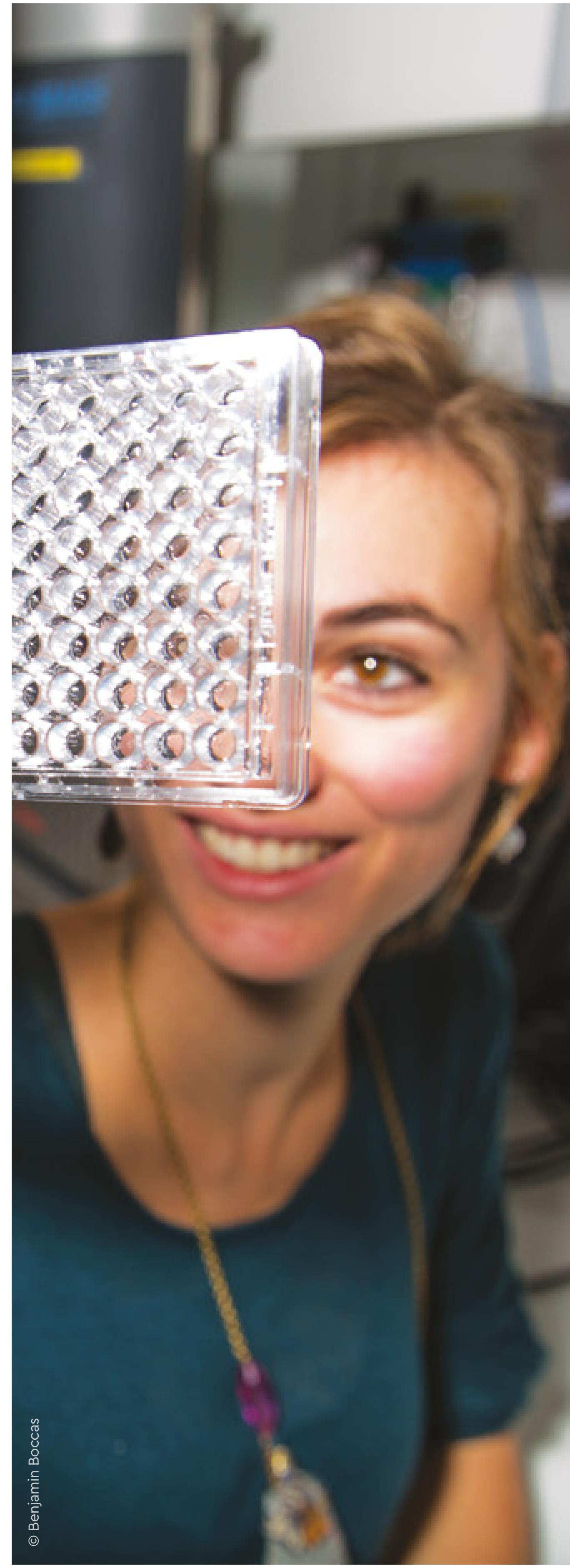
An expert in the art of breaking down barriers between basic and applied research, ESPCI Paris can boast one patent application per week, three start-up creations per year, and first place, along with Polytechnique, for French engineering schools in the prestigious Shanghai ranking. To support the ambitions of this impressive establishment, in 2010 Jacques Prost, the school's Director General, Jean-Louis Missika, Deputy Mayor of Paris, and Henri-Dominique Petit, President of ESPCI Alumni, created the ESPCI Paris Fund. Their goal was to mobilize the school's community along with external partners to maintain ESPCI's novel structure and take even better advantage of the school's unique expertise in transforming basic research into truly useful applications and new businesses.

Jacques Lewiner, Director of Research under Pierre-Gilles de Gennes, has presided over the fund since its creation. A serial entrepreneur and ESPCI graduate, he has stopped keeping track of the start-ups that have resulted from his research in medical imaging, telecommunications, sensors, fire detection, Internet, embedded systems, cell analysis, and more.

STUDENT VOICES

"The support provided by the ESPCI Paris Fund enabled me to have a unique experience working within a high-level research group at Harvard. This precious help guided my choices in my 4th year and strongly influenced my PhD research."
Antoine LAINÉ (132th)

"I'm grateful to the ESPCI Paris Fund, which helped me when I arrived in Paris. It allowed me to achieve my dream of becoming a student-engineer at ESPCI. Without this financial help, my career plan would never have gotten off the ground."
Elias-Nicolas ABEDELNOUR (135th)



THREE QUESTIONS FOR JACQUES LEWINER

JACQUES LEWINER
President of the ESPCI Paris Fund

What is the Fund's philosophy?

A unique approach to teaching and research has made ESPCI Paris attractive to a number of inventive and creative minds for over a century. The ESPCI Paris Fund, thanks to its generous donors—graduates, parents of students, friends and industry partners —enables us to contribute to the excellence and influence of this approach. The ESPCI Paris Fund is celebrating six years of existence. In these first few years, we have concentrated our activities on support for disruptive innovation. Indeed, it was essential for ESPCI to generalize the transfer of innovations developed at the school and encourage researchers to create start-ups. The ESPCI Paris board of directors wished to demonstrate its support for PSL, the ambitious project for a new research university in Paris. To this end, in July 2016, ESPCI decided to transfer the Fund's development activities to PSL. This should enable ESPCI Paris' strategy to be applied at the PSL level and in doing so, help take an important step forward regarding innovation's applications for economic development.

What role do you envision for the Fund within this new context?

One of the Fund's primary missions has not changed: encourage the school's development and influence. We will continue with and increase patronage. Since 2011, the Fund has raised 6 million euros in donations that has helped 70 students successfully complete their education at the school, including 12 doctoral candidates and postdoctoral students. In addition, 59% of these donations have been allocated to teaching and research development. We are proud of these accomplishments, but have only scratched the surface of what is possible. Donations are vital for the institution and play a major role in implementing the school's strategic projects.

How do you intend to achieve this?

The Fund's board of directors appointed Corinne Degoutte as Director of Patronage. Corinne, who has extensive experience in the field, joined us in early January 2017. She will help the ESPCI Paris Fund implement a longterm philanthropic process at the core of our ecosystem—school, Alumni, Fund.

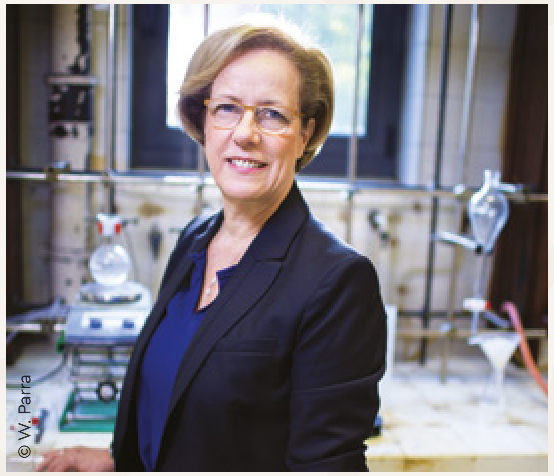
© W. Parra

EDUCATION

BECOMING AN INNOVATION ENGINEER
TRAINED BY THE BEST TEACHERS
AND RESEARCHERS

PAGE 21

FOSTERING INTERDISCIPLINARY STUDIES



Véronique Bellosta,
Dean of Academic Programs at ESPCI Paris

IN WHAT WAY DOES AN ESPCI EDUCATION DIFFER FROM THAT OF OTHER ENGINEERING SCHOOLS?

For starters, ESPCI fosters a unique interdisciplinary approach. Our students acquire solid training in physics, chemistry and biology, which provides them the widest choice of careers possible, not only within these three fields, but also where they intersect. In learning reasoning methods used by physicists, biologists and chemists, which are each very different, they can tackle, for example, a physics problem from a chemist's or a biologist's perspective and in doing so, develop a strong capacity for innovation. Another particularity lies in the fact that the ESPCI curriculum takes four years to complete: three years to obtain an engineering diploma, followed by an additional year to obtain the ESPCI graduation certificate. A broad range of choices exists for the fourth year, which can be spent in France or abroad: students generally pursue a dual diploma or, in a majority of cases, a master in research, which makes sense, considering that 60 to 70% of our students continue their education with a PhD.

HOW DOES THE SCHOOL GENERATE SUCH INTEREST IN RESEARCH?

A third particularity of ESPCI lies in a pedagogical approach based on learning through research and experience; during the first two years of an interdisciplinary core curriculum, 50% of teaching time is spent on practical work in the school's laboratories. The ratio increases in students' third year, during which they complete a four- to six-month industry internship in France or abroad, and an academic research project lasting at least eight weeks, which can be carried out in one of the ESPCI laboratories, a PSL member institution, or abroad. Every ESPCI teacher is a professor-researcher or researcher: practical work sessions and mentoring provide teachers opportunities to exchange with students about their research and pass on their enthusiasm.

WHAT ARE THE LATEST DEVELOPMENTS AT THE SCHOOL IN TERMS OF TEACHING METHODS?

Introduced in 2013, the "team science projects" (*projets scientifiques en équipe* or PSE) have since taken off. Divided into groups of three, students choose a project on a topic ranging from physics to biology and carry it out from end to end, during the last semester of their first year and the first two semesters of their second year. Incredibly educational, this concept is popular with students: they find themselves confronted with real research problems and must find solutions themselves. Beginning this year, they will present the results of their PSE in the form of short videos that will enable them to communicate outside the school, to illustrate their resumes, and more.
We are very committed to a form of teaching which is rather specific to ESPCI called "preceptorship or mentorship," introduced a number of years ago by Pierre-Gilles de Gennes, and which enables students to actively participate in their education. In small groups of 5 or 6, students reflect on a subject taken from recent research and suggested ahead of time by a professor-researcher or a researcher. They submit a written paper before attending a correction-discussion session. We are currently testing a new teaching method that we call "super practical work" and which consists of supervised practical work carried out in smaller groups with the possibility to hand in work before the discussion-correction. We also have plans for "inverted classes" to replace some of our lecture classes. Similar to preceptorships, students arrive in class already having worked on the subject and the session becomes a sort of exchange with the teacher. These are interesting possibilities, but to develop them, we need to free up time for the students, whose schedules are already incredibly dense. We have to find a way to lighten them while maintaining our high standards, an interdisciplinary approach, and without modifying the portion of experiment work that constitutes our strength.

THIS EDUCATION ALSO TEACHES THEM TEAMWORK.

Teamwork is a major goal of ESPCI's educational approach. There is a considerable amount of information to absorb and skills to master. If students were to try to do it all alone, they would wear themselves out. They must work together, and everything is designed to help them do just that (practical work, preceptorships, PSE). The school is human-sized, everyone knows each other, there's a positive energy and people help each other out. Last year, a new student arrived from the French university system and had a hard time the first semester, but really took off in the second, thanks to support and help from her peers. We do everything we can to identify students who are in difficulty as early as possible and provide them with support at every level, from the Dean's office to teachers, almost all of whom are permanently present on campus. I'd like to emphasize that at ESPCI, mutual assistance between students is not an empty phrase. We have regular proof that the best really do help those experiencing the most difficulty.

STUDENTS ARE VERY INVOLVED IN ORGANIZING THEIR ACADEMIC PATH.

The first two years of the program are the same for all students. We're considering introducing a certain degree of personalization during these first two years, while maintaining a strong core curriculum with foundational classes in physics, chemistry and biology. In the third year, students are free to choose their academic pathway – Physics, Physical Chemistry, Chemistry or Biotechnology – and choose electives. The way third-year schedules were first designed meant that some electives were inaccessible to certain pathways: at the request and with the help of students, we've worked to adjust schedules in order to make a maximum of electives accessible to all. Students know that the school administration is here to help them. Our objective is for each student to find his or her own path and be happy in what they do, and for them to be prepared to attain their future goals, and they know that. They are therefore very motivated when it comes to giving feedback on this or that course, to suggest modifications or new partnerships. Even if the request comes from a single student, as long as it is reasonable and well presented, we will try to find a solution.

ARE THERE EXAMPLES OF STUDENTS MOVING BETWEEN THE DIFFERENT PSL SCHOOLS?

There is much movement at the fourth-year master level and will increase with the new PSL masters. The dual diploma agreement established with École des Mines ParisTech generates a lot of interest from our students. For the engineering cycle, together with École des Mines ParisTech and Chimie ParisTech, we've put in place two "PSL weeks," one in November and the other in March. These are reserved course weeks during which ESPCI students may attend classes at Mines or Chimie ParisTech, and visa versa. All second-year foreign language classes are shared by students of ESPCI and Chimie ParisTech. Starting this school year, Chimie ParisTech students have access to all classes in ESPCI's third-year biotechnology option. We're actively working to give our engineering students the possibility to attend other classes in PSL establishments. The goal is for each PSL student to acquire 15% of their ECTS in this manner. It's one more reason for us to work on lightening schedules to allow for movement between establishments.

AN INNOVATIVE 3 + 1 CURRICULUM

The three-year ESPCI engineering degree gives students the possibility to refine their specialty or undertake a masters program. This pathway is popular with the majority of graduates.

The engineering path at ESPCI is a three-year program followed by an optional fourth year. The first two years comprise a core curriculum shared by all students, with foundational courses in physics, chemistry and biology, supplemented by foreign language and socio-economic modules. In this way, students discover the rigor of physics concepts, the complexity and variety of living organisms and biology, and the originality of chemistry-based approaches. Practical work accounts for half of the program in order to familiarize student-engineers with a maximum of experiment techniques: from spectrometers to chromatographs and from laser optics to microfluidics. Another crucial element of these first years is discovering team work, notably through the "scientific team project" (PSE), which begins in the final semester of the first year and continues over two semesters the following year. Students work in groups of three on a project of their choosing which they conduct from start to finish. Defining objectives, establishing a bibliography, ordering materials, developing experiments, utilization, and more – the work may even extend to publication or a patent application. The subject is open, and may range from physics to biology; it might be tied to a research theme, but it may also respond to the needs of a nonprofit organization.

A THIRD YEAR TO CHOOSE A SPECIALTY

Specialization for student-engineers takes place in their third year, when they have the opportunity to choose to major in chemistry, physical chemistry, physics or (since January 2015) biotechnology. The year begins with a four- to six-month industry internship in a company. This is followed by four months of classes in their chosen specialty, then a minimum eight-week-long laboratory-based research project. Supported by 522 researchers, professor-researchers, doctoral candidates and postdoctoral students working in 9 research units affiliated with CNRS, student-engineers benefit from customized academic support. The school also organizes coaching and co-orientation sessions, provides help finding internships, and more.

"Foundational courses in physics, chemistry and biology."

A FOURTH YEAR TO FINE-TUNE TRAINING

The majority of students choose to enroll in a fourth year, seizing the opportunity to deepen their already comprehensive knowledge and skills in fields like health and human biology, energy, mechanics/acoustics, materials, the environment, organic chemistry, and more, often in the form of a masters degree. Numerous options allow students to circulate among the different establishments associated with PSL, and new programs are being created between PSL establishments. In 2015, several requests for new official degree designations were submitted to the French Ministry of Education for masters in the fields of energy, materials, chemical frontiers in living matter, and more. The Masters Degree in Energy debuted the 2016 school year with six students. New degree requests are in the works: one in life sciences and another in health engineering. During their final year, student-engineers also have the possibility to obtain a dual degree from prestigious international institutions (Unicamp in Brazil, Tongji in China, Tel Aviv in Israel) and grandes écoles in France (HEC, ESSEC, Mines ParisTech, IOGS, Agro ParisTech and others).

An industry internship in France or abroad

The school's very name states its goal loud and clear: "École Supérieure for Industrial Physics and Chemistry" voices a clear desire to encourage connections between education and industry. In addition to establishing industry chairs and mentorship for graduating classes, the school requires student-engineers to complete a four- to six-month internship at the start of their third year. In this way, companies benefit from their interdisciplinary education and their familiarity with experiment-based laboratory research: students are open and receptive, and able to hit the ground running.

Student-engineers may also carry out an internship in a company outside of France. In recent years, nearly 60% of students have taken advantage of this option, in the United States, Japan, the European Union, the Arab Emirates, Oman, Canada, China, Switzerland and elsewhere. During this internship, they are expected to lead a project, most often in research and development, but sometimes in production (supply chain, quality, logistics, etc.).

At the end of this period, future engineers are evaluated based on their written report (graded by their internship mentor, an ESPCI Paris professor-researcher), the assessment of their industry internship director, a closed-session oral defense before a three-member jury, as well as an inquiry into the company's socioeconomic context.

RECRUITMENT: HOW TO BECOME AN INNOVATION ENGINEER

Student-engineers are recruited via a competitive exam or degree-based admission, two integration paths that favor a diversity of educational, cultural and individual backgrounds – all of which contributes to intellectually rich graduating classes.

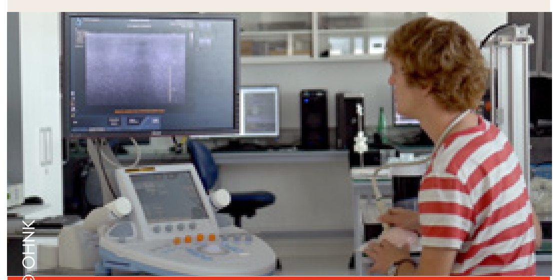
In privileging small year-groups (90 students), ESPCI provides individualized support to each student-engineer. Sixty are recruited via a competitive exam during their second year of preparatory classes for the *grandes écoles*. The remaining thirty are admitted based on earned-degrees (CPGE MP or PSI or L2, DUT or L3 university graduates) after application review, oral exams, including an interview, or via a selection process for students from preparatory classes at the Fédération Gay-Lussac. The latter, which brings together twenty French chemistry schools, may grant four students admission to ESPCI each year. Several pathways in particular enable the school to welcome first- and second-year international students (14.5%) who enrich each graduating class with their different cultures and experiences.

EQUAL OPPORTUNITY AND SOCIAL INCLUSION

Committed to social inclusion and equal opportunity, ESPCI has established its own system, the Joliot scholarships, to support student-engineers with financial difficulties and enable them to pursue their education as worry-free as possible (the scholarships match CROUS financial aid). The administration's objective is clear: no financial problem should prevent a student from continuing his or her education in decent conditions. The Joliot scholarships are funded by tuition fees and financial aid from ESPCI Alumni. The ESPCI Paris Fund also help students, particularly with internships or international study projects. Fourth-year merit scholarships are offered by ESPCI Alumni and companies (Michelin, Total, Safran, Saint-Gobain...). ESPCI Alumni also grant zero-interest loans, guarantees, donations and more to support their peers. One-third of the school's students receive some form of financial aid.

NEARLY 70 DOCTORAL CANDIDATES WELCOMED EACH YEAR

The ESPCI Paris laboratories train high-level PhDs destined for careers in innovation and research in industry or academic fields. In late 2015, the school had 233 doctoral candidates. Each year, it welcomes more than seventy new candidates, spread across thirteen partner doctoral schools (École doctorale, or ED): ED 130 Information technology, telecommunication and electronics; ED 158 Brain, cognition and behavior; ED 390 Advanced technology and process engineering; ED 518 Condensed matter and interfaces, etc. In 2015, ten out of sixty-three PhDs were funded by doctoral schools. Other funding sources exist, notably through CIFRE measures – Industrial convention for education through research (eight in 2015), the ANR – National Research Agency (four), and the DGA – Defense procurement agency (2.5).


© OHNK

"The administration's objective is clear: no financial problem should prevent a student from continuing his or her education in decent conditions."

CAREER ORIENTATION

80% industry, 20% research

ESPCI trains engineers for every industrial sector using an educational approach founded on interdisciplinary learning – and leading companies have caught on!

The numbers speak for themselves: 80% of engineers who graduate from ESPCI are hired in large part by companies in research and development. On average, they are recruited a month after graduation, with an average annual gross salary of 41,000 euros. Be it in the chemical industry, energy, aerospace, electrical and information systems material or in the public sector, ESPCI engineers are appreciated for their capacity for interdisciplinary thinking and their skills in the field of innovation. Consequently, industrial groups like Saint-Gobain, L'Oréal, Arkema, Airbus, Safran and others, as well as large research organizations like CNRS or CEA recruit ESPCI graduates.

Optimize relationships with businesses
To encourage speedy recruitment of engineer graduates, ESPCI is hosting an increasing number of events: visits to industrial sites, company presentations within the school, round tables, job interview simulations, participation in trade fairs, forums, breakfast with Le Cercle de l'Industrie (in May 2015 with Jean-Louis Chaussade, General Director of Suez Environnement, in November 2015 with Jean-Dominique Senard, President of Michelin), involvement in events held by the Business Relations Committee, and more.

Productive research units
ESPCI researchers are trained to anticipate industry needs in order to pioneer inventions. ESPCI Paris houses nine cutting-edge research units, all affiliated with CNRS and operating at the frontier of basic scientific knowledge and industrial application. They engage with many different fields, from polymers to telecommunications, from nano-biophysics to organic synthesis, from environmental science to biomedical imaging, from neurobiology to microfluidics, from soft matter to quantum physics. Researchers publish more than one article per day in the best international reviews, file a patent application per week and create several start-ups each year to highlight the inventions and discoveries arising from their research.

© W. Parra

MORE THAN EVER OPEN TO THE WORLD
AND PROMOTING EDUCATIONAL EXCELLENCE

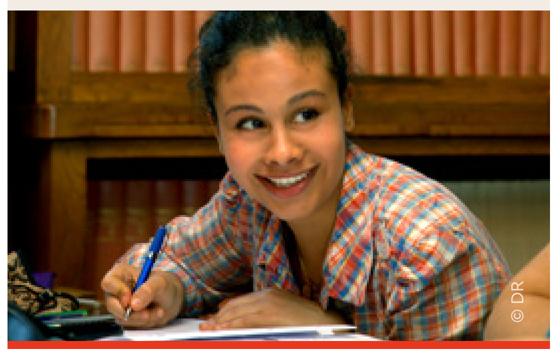
ESPCI's international scope is woven into the very fiber of its educational program, from where industry internships are located to research projects, dual diplomas, and student-engineer and professor-researcher recruitment.

The school's reputation within the international scientific community, as well as among multinational corporations, directly benefits student-engineers by giving them the opportunity to carry out internships and/or research projects around the world. As soon as they finish their first year, they can continue with an internship in a company or in a laboratory. At the beginning of their third year, their six-month industrial internship may take place abroad; the same goes for their research project in an academic laboratory. Time spent abroad is now a required element of the curriculum (industry internship or research project in the third year). The fourth year is full of possibilities as well, including a dual-degree carried out in partnership with a foreign university such as the University of Novossibirsk (Russia) in mathematics, the University of Tongji (China) in architecture and urban engineering, Northwestern University (United States) in materials science, Polytechnique in Montreal (Canada) in industrial engineering, and the University of Doshisha (Japan) in science and engineering, and medical and life sciences.

"ESPCI trains versatile engineers. They will be all the more efficient if they are equipped with scientific and cultural open-mindedness."

ATHENS: ENCOURAGE EXCHANGES WITH EUROPEAN TECHNOLOGICAL UNIVERSITIES

The goal of the ATHENS program (Advanced Technology Higher Education Network Socrates) is to encourage student, teacher and researcher exchanges between major European technological universities and ParisTech schools. Each session provides 30 hours of scientific courses and 10 to 15 hours of sociocultural activities, which are validated by a knowledge test given by the host institution. A total of five thousand European students enroll each year in this exchange program.



© DR

STUDENTS AND RESEARCHERS RECRUITED WORLDWIDE

An increasing number of international student-engineers are being recruited in the first and second years in order to form enriching, diverse year groups. ESPCI welcomes students from countries including Morocco, Tunisia, China, Japan, Brazil, South Korea, Vietnam and Cambodia. Teaching staff comes from increasingly international backgrounds as well, especially regarding courses taught in English.

Recently, the New Zealand geneticist Paul Rainey and his team joined the Chemistry Biology Innovation laboratory, capitalizing on the latest microfluidics tools to carry out their work, and preparing the establishment of a new master in life sciences. Additionally, PSL, as well as the Michelin, Total and Saint-Gobain chairs, support funding and accommodation for foreign researchers and professors.

© W. Parra

THREE QUESTIONS FOR

BÉNÉDICTE RAVIER
Head of International Relations

What is your strategy for strengthening exchanges with foreign institutions?
As far as admissions for international students are concerned, we're focused on two countries in particular: Brazil and China. We recruit through Polytechnique's foreign competitive entrance exam, but also through recruitment coordinated by ParisTech. The school's goal is to increase visibility and establish dual degrees and co-supervised theses with Chinese and Brazilian universities ranked high on the Shanghai Ranking. We want the best. We also draw on networks of scientific collaborators to strengthen our foundation and reach larger geographical regions. For example, we developed a co-supervised PhD with the University of Tel Aviv in Israel. In fact, this will be the subject of a meeting between professors from Tel Aviv and ESPCI in 2017, followed by a doctoral candidate exchange.

How do you welcome international students?
Each international student must have an advanced-intermediate or B2 level in French. The reality is more complex and international students face several challenges: a triple training in physics-chemistry-biology that they didn't necessary acquire in their home university, mastery of the French language and learning a new culture. Through the work of the Student Office, we are committed to several activities to help them integrate: each international student is supported by a French mentor, and an event is held where they are invited to present their culture and contribute to breaking down stereotypes. I also help them find scholarships to finance their engineering education. .

Why is study abroad so important today?
ESPCI trains versatile engineers. They will be all the more efficient if they are equipped with scientific and cultural open-mindedness. Considering that researchers progress within international communities, they may as well get a foot on the ladder as early as possible. An initial exchange gives them the chance to engage in movement that might lead them to undertake a PhD abroad. For the school, it's very positive in terms of our brand image: it signifies that we are capable of training students who aren't afraid to leave France.

RESEARCH

CONNECTING BASIC AND APPLIED RESEARCH
WHILE AIMING FOR EXCELLENCE
IN A NUMBER OF SCIENTIFIC FIELDS

PAGE 31

REMOVE BARRIERS BETWEEN DISCIPLINES

Rémi Carminati,
Dean of Scientific Programs at ESPCI Paris

ESPCI PARIS HAS A STRONG TRADITION OF RESEARCH, AS EVIDENCED BY ITS ILLUSTRIOUS GRADUATES.

Yes, but not only. The school has a tradition of excellence in basic research, with no fewer than six Nobel Prize winners, but it is also very committed to concepts of technological innovation and the social impact of research. Our "greats" were more than thinkers: Marie Curie, after discovering radioactivity, left for the front with an ambulance to use X-rays to care for those injured during World War I. Paul Langevin, who made many fundamental discoveries in the field of magnetism, including Brownian motion, also developed sonar. He can be seen in photos testing his system with engineers in the Toulon harbor on the eve of World War II. Actually, here at the school, we rarely use the words "basic research" and "applied research," because the two constantly overlap.

WHAT IS THE SCHOOL'S STRATEGY WITH REGARD TO RESEARCH?

ESPCI is a rather small structure: researchers (permanent positions, doctoral candidates and post-doctoral students) represent 522 people. Our policy is simple: we recruit from the highest level and we give our researchers as much freedom as possible. We make a daily effort to detect scientific potential, often where fields overlap. The moment a project exhibits a strong potential for disruption, whether it's very applied or very basic in nature, we lend a hand, we encourage. The structure's small size enables us to be rather flexible and reactive, and thus make precise decisions. We don't tell our researchers what to do. Our joint research laboratories are all under the dual supervision of CNRS and ESPCI, and some have other supervisors: Inserm, UPMC, Paris Diderot, etc. Unit directors regularly meet with the Dean of Research during the Internal Scientific Committee meeting, and there is no intermediary structure. Unit directors are free to organize their laboratories as they wish, which explains the variety of internal structures. For example, Gulliver has four distinct teams, while the Langevin Institute is structured according to four rather open scientific themes, with most of the researchers working between several. As long as it works, we don't impose a structure.

ESPCI HAS A REPUTATION FOR WORKING AT THE INTERSECTIONS OF SCIENTIFIC FIELDS.

That's true, we don't make a clear distinction between physics, chemistry and biology: the different disciplines are free to work together. Incidentally, there are no departments at ESPCI. The Soft Matter and Chemistry laboratory develops glues to suture biological tissues and the genetic evolution team uses discoveries made by the microfluidics laboratory. This interdisciplinary approach is enriching and the source of many innovations. We stand by it wholeheartedly.

CAN YOU GIVE US AN OVERVIEW OF SUBJECTS INVESTIGATED AT THE SCHOOL?

The various laboratories cover a quasi-continuous spectrum that can be represented on an axis starting at physics (the LPEM with material physics; Langevin Institute with wave physics; the PMMH and the Gulliver laboratory), moving towards chemistry (SIMM and MMC) and little by little moving towards biology (CBI), to culminate in far more "life science" oriented disciplines (the Brain Plasticity laboratory and the USR Biology and Proteomics). In all, we publish more than 500 articles a year, around 3.5 per researcher.

EVERYTHING NECESSARY TO GO FROM THEORY TO PRACTICE...

Yes, indeed, but we also strongly believe in the "reverse" – industrial applications that stimulate basic research. A very good historical example is the publication by Sadi Carnot (who did not go to ESPCI!) in which he demonstrates the second principle of thermodynamics. He begins with a pure engineering problem – optimizing steam engines – and the result of his search for ways to maximum output was the second principal of thermodynamics, a fundamental idea. This shows that the virtuous circle works in both directions. We put this idea into practice here: people interact on a daily basis, without complexes, free from any notion of hierarchy between basic and applied research, and thus retain the open-mindedness needed to recognize potential evolutions.

"We make a daily effort to detect scientific potential, often where fields overlap."

WHAT AREAS OF RESEARCH DOES THE SCHOOL PLAN TO DEVELOP IN THE FUTURE?

We intend to keep developing subjects found at the intersections of physics-chemistry-biology, especially for applications in health and medicine. We've achieved good results in this field, but we can go further. A new unit has recently been created for porous materials studies (Porous Materials Institute), with multiple applications for health, energy and the environment. We could also take a stronger position on energy: the SIMM laboratory is working on new approaches to membraneless fuel cells. At the LPEM, quantum dots could improve photovoltaic cells.

AND IN TERMS OF STRUCTURE?

We now belong to PSL, which offers great potential for developing research in Paris, and which is practically the top-ranked French university, according to the Shanghai Ranking. We welcomed a new team that is working on porous materials chemistry. We're setting up a shared laboratory with the École Normale Supérieure, with the support of PSL, for the occasion. The Porous Materials Institute was created September 1 and is slowly getting its footing. Another challenge is to ensure that improvements planned for 2018 do not impact the research dynamic. Most importantly, these improvements will enable us to adapt our facilities to future research needs.

PRIZES AND DISTINCTIONS
A SHOWER OF AWARDS

Our research teams are recognized at both national and international levels, as demonstrated by the prizes and distinctions received each year by our researchers and student engineers.

2015

- **The European Patent Office's 2015** European Inventor Award in the research category given to Ludwik Leibler
- **CNRS Bronze Medal**: Stellios Arseniyadis
- **2 L'Oréal-UNESCO For Women in Science Prizes** awarded to Laura Magro and Marine Bézagu
- **Fondation NRJ Scientific Prize** awarded to Mickaël Tanter
- **Prix La Recherche** in the biology category awarded to Joelle Vinh and Yann Verdier
- José Eduardo Wesfreid received the **French Senate Meda**l
- Rémi Carminati was named a **Fellow of the Optical Society of America**
- Elie Raphaël was promoted to **Fellow of the American Physical Society**

2016

- **French Academy of Science award** for "major French scientific advances in biology": Gaëtan de Lavilleon and Karim Benchenane
- **The City of Paris Jean Hamburger Award for Medical Research** awarded to Karim Benchenane
- **CNRS Bronze Medal** given to Olivier Couture (Langevin Institute)
- **Berthelot Medal of the French Academy of Sciences** given to Christian Serre
- **Jean Langlois Dissemination Award** given to Marie Leman, Axel Huerre
- **2016 Jean Langlois Prize for Research** awarded to Elie Raphael
- **Le Monde Research Prize**, and the **Chancellery of Paris Universities Aconati-Visconti Prize** awarded to Marine Bézagu
- **Chancellery of Paris Universities Gandi Prize** awarded to Charlie Demené
- **Susan P. and Barry M. Trost Award in Organic synthesis** from the University of Pennsylvania and Tarrant Distinguished Visiting Professorship of Organic Chemistry from the University of Florida awarded to Janine Cossy
- Matteo Ciccotti received the **Darshana and Arun Varshneya Frontiers of Glass Science Lecture** from the American CeramicSociety; he also received the **Science Award from Engineering Conferences International**
- **Fondation pour la Recherche Médicale Grand Prize** awarded to Mickael Tanter
- Flavio Dormont is the laureate of the **2016 Engineers of the Future Trophy** in the category "International Engineer"
- **Thesis prize from the French Rheology Group and the French Polymer Group** awarded to Charlotte Pellet
- **The iGEM Competition gold medal** awarded to 6 student members of the iGEM Pasteur team for the MOS(KIT)O Project
- **2 L'Oréal-UNESCO For Women in Science Prizes** awarded to Charlène Gayrard and Pascaline Hayoun

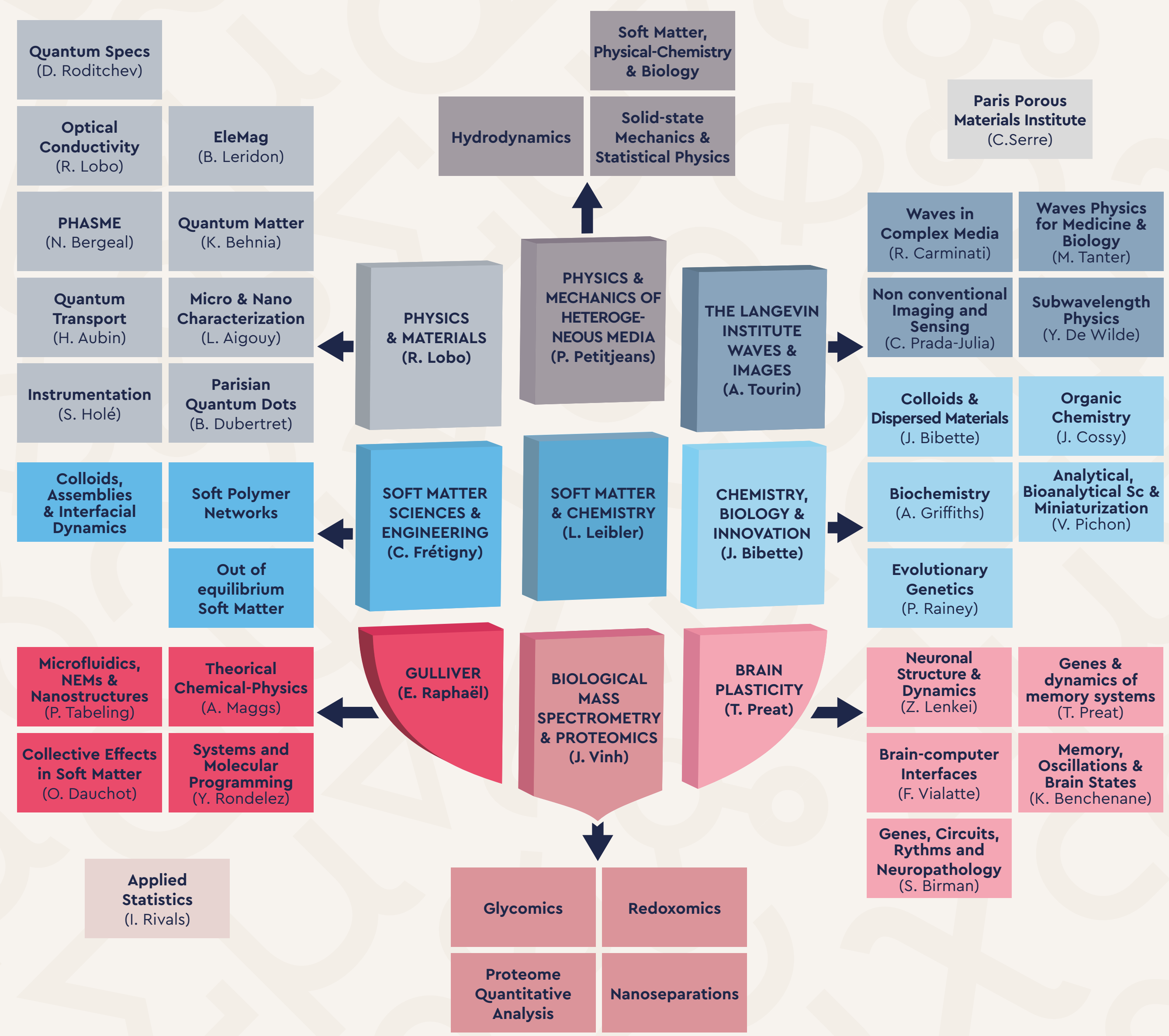
ERC

The European Research Council (ERC) supports scientific excellence in Europe through funding for innovative research projects.

Consolidator Grant 2015: Anke Lindner
Advanced Grant 2015: Costantino Creton
Consolidator Grant 2015: Emmanuel Bossy
Consolidator Grant 2016: Karim Benchenane
Consolidator Grant 2016: Luca de' Medici

SUPPORTING AGILITY AND EXCELLENCE
9 JOINT RESEARCH LABORATORIES

In addition to its educational mission, the school welcomes research laboratories closely associated with CNRS, UPMC (Paris 6), the Université Paris Diderot (Paris 7) and Inserm, which remunerate permanent researchers and professor-researchers. Many researchers and professor-researchers are employed by these governing institutions.



CHEMISTRY BIOLOGY INNOVATION CBI

© W. Parra

110 people

90 post-docs

7 start-ups created

THREE QUESTIONS FOR

JÉRÔME BIBETTE
Director of CBI joint research laboratory

What idea guided the creation of this laboratory?

The idea was to create a unique and truly multi-disciplinary joint research lab that can handle everything from basic research to applied innovations, that produces start-ups and generates employment. We started from a single observation: the person most capable of developing a discovery is often the one who was very closely involved in making it technologically viable during the phase of scientific creation.

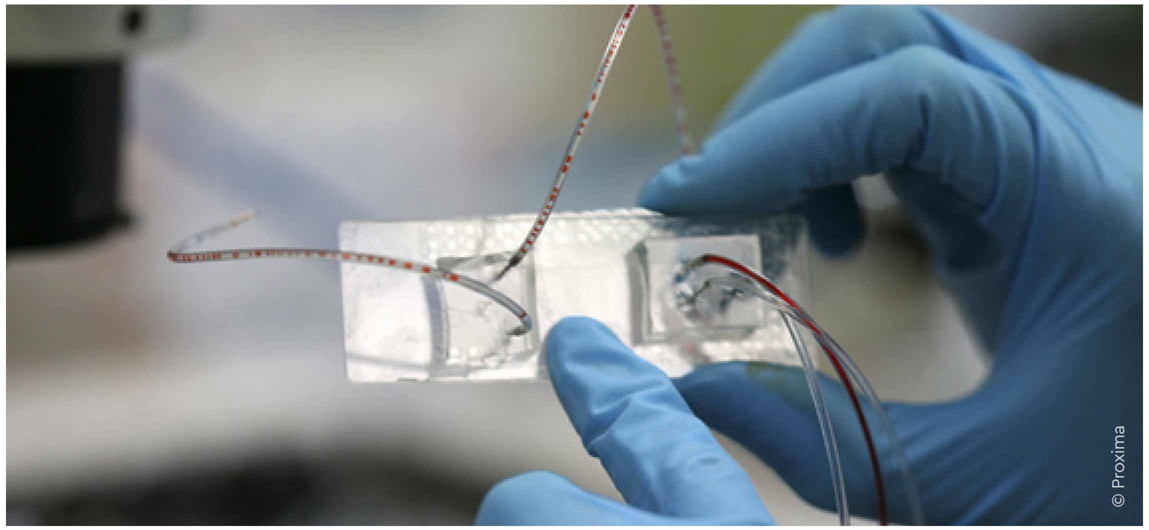
How is the laboratory structured?

Five laboratories make up this research laboratory, which includes expertise in fields ranging from physics to biology: the Colloids and Dispersed Materials laboratory, which I direct, the Biochemistry laboratory directed by Andrew Griffiths, Paul Rainey's laboratory, which works on genetics and evolution, the Analytical Chemistry laboratory directed by Valérie Pichon, and the Organic Chemistry laboratory directed by Janine Cossy. We're aiming for a global approach: we develop new tools to explore the biological world, founded on interface physics, dispersed media, hydrodynamics, and analytical, organic and biological chemistry. The miniaturization of analytical systems, the development of high-speed tools, their application to genetics and evolution, the immune response and microbiology, are some of our laboratory's central themes.

The CBI laboratory is also start-up oriented...

That's one of our goals, along with publishing in the best journals; we are deeply focused on transforming science into socially beneficial applications. We advance research, but also our society, notably by creating jobs. Since the joint research unit was founded, we've created seven businesses, all of them successful, having generated several hundred skilled jobs to date.

DROPLET-BASED ANTIBODIES



HifiBio uses microfluidic technology to discover new medications.

Microfluidic technology has applications in many fields and has enabled several start-ups incubated at the CBI to take off. Among them, HiFiBiO, founded in 2013, is a wonderful example of success. As its name indicates, the company specializes in high-throughput screening of certain biological expressions, in this case immune response, and antibodies in particular, secreted by B lymphocytes.

This technology is based on the ability to create extremely small droplets (roughly 1 picoliter in size, in other words, a thousandth of a billionth of a liter!) while keeping them intact and perfectly separate from one other. Using technology developed at ESPCI, these droplets can be created very quickly (3,000 per second) and in such a way that each one contains just a single cell, allowing for much more precise analysis.

Once isolated, it is possible to use fluorescence to identify which cells produce antibodies (around 1% of the total) and which produce the sought-after antibodies in particular (which could represent a ten-thousandth of the total). This implies analyzing millions of cells, a feat made possible by this technology, which employs microfluidic systems and enables dozens of millions of analyses to be carried out daily.
Once identified, the best antibodies are isolated, labeled by a system developed by HiFiBiO, then sequenced (antibodies comprise four chains, two light and two heavy, characterized by their sequence). In this way, the best can be cloned rapidly. The entire cycle takes twenty-five days, in comparison to several months using the classic method (which implies long, cumbersome and far less precise Petri cultures).

The company, now divided between two sites (one in Paris and one in Cambridge, in the United States), quickly won contracts with a variety of pharmaceutical companies, including Pfizer and Johnson & Johnson, and even the American Department of Defense. HiFiBiO prefers to operate as a partner, rather than as a simple service company; each order is an opportunity to share procedures and expertise, and obtain the rights and royalties on any future discoveries. The initial contracts enabled the technology to be brought to maturity and herald a number of other contracts.

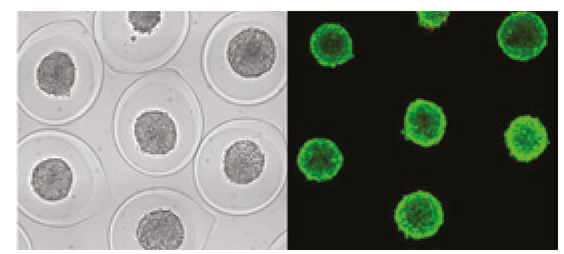
hifibio.com

IN BRIEF

Recreate functional tissue

Everything started ten years ago with the discovery of semi-permeable elastic capsules and how to make them. The tool very quickly exceeded expectations: thereafter, it was possible to recreate living human tissue using frozen cells. Within the CBI, a longterm project was initiated: the discovery met with initial success in cosmetics – after 6 years in development, a spin-off was sold to Chanel in 2015. In parallel, the CBI team applied the same discovery to researching the reconstruction of human tissues, like the liver. The laboratory developed methods to reconstruct tissue in these 200 μm biocompatible capsules – functional parts of the liver on which to carry out all manner of tests, paving the way for many applications in pharmaceutical research. The last step will be to create a dedicated start-up paired with a company already well-established on the market. This project was devised and carried out in its scientific and entrepreneurial aspects by the laboratory, from start to finish.

FURTHER READING: ***Controlled production of sub-millimeter liquid core hydrogel capsules for parallelized 3D cell culture***, *H. Doméjean, M. de la Motte Saint Pierre, A. Funfak, N. Atrux-Tallau, K. Alessandri, P. Nassoy, J. Bibette, and N. Bremond , Lab Chip, 2017, 17, 110–119.*



Murine colorectal cancer cells.

Exploring microbiomes with microdroplets

MilliDrop (a start-up created in 2015) uses microfluidics to study micro-organisms: Petri dishes are swapped for thousands of microdroplets several hundredths of a nanoliter in size, each perfectly isolated from one another and in a perfectly controlled environment. Several thousand droplets allow for as many reactions to be observed simultaneously, without evaporation or contamination between cultures. This system is revolutionizing biology (see HiFiBiO on the previous page or the evolution machine below), but also promises a multitude of other applications, notably in agriculture with the exploration of soil diversity, bacterial study (it is possible, for example, to grow single cells directly in human urine without amplification methods), microbiome studies (pedological, cutaneous, etc.).

FURTHER READING: ***Growing microbes in millifluidic droplets***, *L. Boitard, D. Cottinet, N. Bremond, J. Baudry, J. Bibette, Eng. Life Sci. 2015, 15, 318–326.* ***Digital antimicrobial susceptibility testing using the MilliDrop technology***, *Jiang L., Boitard L., Broyer P., Chareire A.C., Bourne-Branchu P., Mahé P., Tournoud M., Franceschi C., Zambardi G., Baudry J., Bibette J., Eur. J. Clin. Microbiol. Infect. Dis., 2016, 35 (3), 415–422.*

The evolution machine is working

One of the CBI's most incredible developments is the "evolution machine." This tool can be applied as easily to the evolution of a single microbial strain as to the evolution of interactions between several species that lead to development of a community. This hypothesis was introduced by Paul Rainey as soon as he arrived at CBI. Originally from New Zealand, this professor, a specialist in evolutionary genetics recruited by the school in 2016, is developing a novel application for MilliDrop technology: ten thousand droplets, each one containing a cell colony with unique genetic characteristics, screened continually, selected, recovered and redistributed depending on needs according to a determined selection threshold. It is thus possible to monitor the environmental conditions which, according to Paul Rainey, are at the root of the most important transitions in evolutionary history. Initially, the work will concentrate on the evolution of heredity, which is dependent on the evolution of interactions. This is an unrivaled tool for the study and selection of gene panels.

FURTHER READING: ***Lineage tracking for probing heritable phenotypes at single-cell resolution***, *D. Cottinet, F. Condamine, N. Bremond, A. D. Griffiths, P. B. Rainey, J. A. G. M. de Visser, J. Baudry, J. Bibette, PLOS ONE, 2016, 11 (0152395).*

LANGEVIN INSTITUTE

© Benjamin Boccas

115
publications in international peer-reviewed journals in 2015

An average of 3 publications per researcher per year

18
patent applications in 2015

1 LabEx

1 EquipEx

PHOTO : Acoustic superlens made from soda cans arranged in a honeycomb network.

THREE QUESTIONS FOR

ARNAUD TOURIN

Director of Langevin Institute joint research laboratory

Can you tell us a bit about the Langevin Institute?

The Langevin Institute is a joint research laboratory created by Mathias Fink in 2009 and shared between ESPCI Paris and CNRS. The laboratory studies wave physics and its applications, and takes an interdisciplinary approach to combining basic research, applied research and business creation. In 2011, the Langevin Institute received the LabEx label (Excellence Laboratory) for the WIFI project (Waves and Imaging: From Fundamentals to Innovation).

What is the guiding philosophy?

The creation of the joint research lab was driven by a desire to connect all types of waves, from acoustics to optics, including water waves and microwaves. Our goal is to understand the propagation mechanisms of all kinds of waves in the most complex and diverse environments, and to use this understanding to develop new instruments for manipulating these waves and imaging these environments.

So the idea is to apply discoveries made on certain waves to others?

That's one of the advantages of having expertise pertaining to all waves gathered in one laboratory. The time-reversal mirrors invented by Mathias Fink in the early 1990s are a case in point: the idea was first proven on acoustic waves. It was then applied to microwaves, which enabled the development of secure broadband communication systems. Then, with more difficulty, it was applied to optics in the form of spatial light modulators to learn to see through opaque environments. Another advantage is learning to blend waves in a single imaging device to take advantage of the contrast produced by one and the resolution afforded by the other. This lies behind the concept of multi-wave imaging. The Aixplorer, a revolutionary echograph that provides tissue hardness maps, relies on this principle. It is commercialized by Supersonic Imagine, a company that was created in our laboratory.

FOUR START-UPS IN TWO YEARS!

One of the strengths of the Langevin Institute is its ability to create applications from the products of highly fundamental research. This involves several steps, including filing patents and launching start-ups. Four companies were founded between 2015 and 2016.

Prototype of a smart wall – The researchers look at one of the reconfigurable electromagnetic mirrors that they have developed. This innovative concept has led to the creation of company GreenerWave in 2015.

GREENERWAVE: SMART MIRRORS FOR ENHANCED COMMUNICATIONS

In the digital era, large amounts of data are being transmitted through wireless networks – inside buildings in particular. Electromagnetic waves are unable to penetrate easily throughout buildings, which can cause poor quality of service. To solve this problem, researchers at the Langevin Institute have developed an innovative system based on reconfigurable electromagnetic surfaces: "real smart mirrors" which recycle the electromagnetic energy in a room. The energy is redirected towards different terminals such as smartphones, tablets, laptops, etc. These real smart mirrors will be integrated into building materials (walls, insulation panels, etc.), or even furniture or decorative objects. They will belong in the habitat of the future. GreenerWave was among the prizewinners of the 18th National Contest Supporting the Creation of Innovating Tech Companies (i-Lab).

LIGHTON: THE FUTURE OF BIG DATA

It all started with a novel idea by a multidisciplinary team (ESPCI Paris, ENS, UPMC, CNRS): designing an optical processor which, when connected to a computer or server, performs operations for big data applications with outstanding efficiency. This concept has led to the creation of LightOn, with the objective to offer an alternative to generic processors (CPUs) and specialized coprocessors (GPUs). Its technology, which consumes only a few watts, seems perfectly suited to the large amounts of data used in genomics and communicating objects. It is also a potential solution to data security and anonymization issues. LightOn received a trophy at the City of Paris 2016 Innovation Grand Prix.

ABBELIGHT: SUPER-RESOLUTION OPTICAL IMAGING

The Abbelight project aims to commercialize a fully automated and easy-to-use 3D micro/nanoscope for cell membrane imaging. This is the result of a six-year collaboration between the Orsay Institute of Molecular Sciences (ISMO) and the Langevin Institute. Innovations include a double-depth observation mode (to visualize the membrane and interior of the cells) and offer axial super-resolution to new nanoscopic techniques. Abbelight will broaden the understanding of the mechanism and effects of drugs targeting membrane proteins.

NEUROFLOWS: FILMING CORTICAL ACTIVITY USING ULTRASOUNDS

Building on the work conducted by the teams of Mickael Tanter and Zsolt Lenkei (LPC), Neuroflows aims to develop a neurofunctional imager for applications in preclinical research. Introduced as the ultrasonic analogue of an MRI, this groundbreaking technique achieves unprecedented spatiotemporal resolution, and to date, it is the only option to perform functional imaging of the entire brain in an animal that is both awake and moving. Neuroflows aims at global marketing of its system to neuroscience research laboratories and pharmaceutical companies. It was among the prizewinners of the 17th National Contest Supporting the Creation of Innovating Tech Companies (i-LAB).

IN BRIEF

Transferring energy between molecules *via* plasmons

The transfer of energy between molecules is an elementary process observed in biology and physics. The process is limited to distances between molecules that are of the order of a few nanometers. By using a silver mirror and replacing the electromagnetic waves with guided waves, known as surface plasmons, researchers at the Langevin Institute were able to increase the distance by a factor of 1,000 – resulting in transfers at the mircrometer scale. This discovery finds potential applications in many fields – from the recovery of solar energy to the study of biological interactions.

FURTHER READING: *Long-Range Plasmon-Assisted Energy Transfer between Fluorescent Emitters*, D. Bouchet, D. Cao, R. Carminati, Y. De Wilde, and V. Krachmalnicoff, Phys. Rev. Lett. 116, 037401 – Published 21 January 2016.

Biomedical imaging with microscopic resolution: the ultrasound revolution

Researchers from the team "Wave Physics for Medicine and Biology" at the Langevin Institute and from the Brain Plasticity Laboratory have developed a super-resolution medical imaging method that uses ultrasonic waves. With this method, inspired by the optics PALM microscopy technique, the scientists were able to non-invasively report the *in vivo* vascular activity in a rat brain with unparalleled resolution. This technique may find many applications in the early detection of cancerous tumors and cardiovascular or neurological pathologies.

FURTHER READING: *Ultrafast ultrasound localization microscopy for deep super-resolution vascular imaging*, C. Errico, J. Pierre, S. Pezet, Y. Desailly, Z. Lenkei, O. Couture and M. Tanter, Nature 527, 499–502 (26 November 2015) doi:10.1038/nature16066.

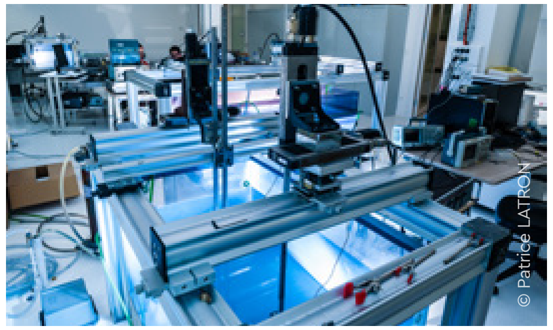
Dense and transparent materials to control light

Until recently, a material that is both dense and transparent seemed like a physical impossibility. Yet materials known as "hyperuniform" combine both characteristics. Composed of glass or plastic, they contain light-scattering particles that form a disordered, albeit not completely random structure. This work paves the way for the development of new materials for photonics.

FURTHER READING: *High-density hyperuniform materials can be transparent*, O. Leseur, R. Pierrat, R. Carminati, Optica 3, 7, 376 (2016). DOI : 10.1364/optica.3.000763.

Giving waves a chance to relive their past life

One of the most well-known inventions of the Langevin Institute is the "Time Reversal Mirror" or TRM, which reflects a wave towards its past life. The system relies on many sensors and rather heavy electronic equipment. With help from colleagues at PMMH, the researchers recently developed a new approach making use of the symmetries between space and time. Without any electronic equipment, they have created an "instantaneous time mirror" which was tested on water waves with spectacular results.



Aquariums in the room dedicated to the study of the propagation of ultrasonic waves in complex environments.

FURTHER READING: *Time reversal and holography with spacetime transformations*, V. Bacot, M. Labousse, A. Eddi, M. Fink and E. Fort, Nature Physics.

An acoustic superlens based on soda cans

Blow in a can of soda: it will emit a sound that is almost pure (420 hertz). By resonating cans arranged in a honeycomb network, researchers at the Langevin Institute have obtained an acoustic metamaterial capable of negatively refracting an audible acoustic wave, in the manner of a superlens.

FURTHER READING: *Negative refractive index and acoustic superlens from multiple scattering in single negative metamaterials*, N. Kaina, F. Lemoult, M. Fink and G. Lerosey, Nature, 525, 77–81 (2015).

GULLIVER LABORATORY

© Steve Murez

45
Rearchers/ doctoral candidates

4
research teams

77
Publications in 2015-2016

THREE QUESTIONS FOR

ELIE RAPHAËL AND OLIVIER DAUCHOT
Co-directors of Gulliver joint research laboratory

Why Gulliver?

E.R: The name Gulliver underlines the diversity of scales studied in the laboratory: from the millimeter (the scale of gravity capillary waves) to the molecule (enzyme mechanisms), to the micrometer (colloids, microfluidics). The laboratory's basic research work combines both experiments and theory.

What are your fields of research?

O.D: The laboratory is divided into 4 teams: Theoretical Physical Chemistry (PCT), Microfluidics, MEMS and Nanostructure (MMN), Collective Effects in Soft Matter (EC2M) and Systems and Molecular Programing (SPM). Together, they cover a large field of research at the intersection of physics, chemistry and biology.

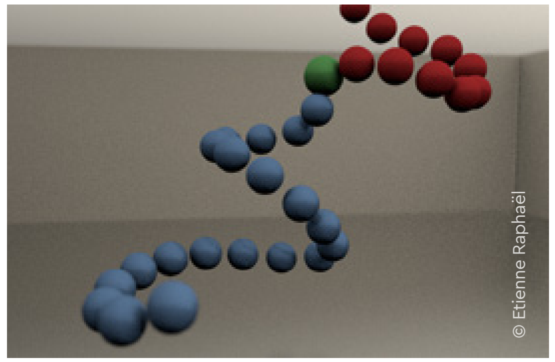
The laboratory is firmly open to the outside world.

O.D: Yes, we are far from the idea of researchers locked away in their ivory towers! Gulliver researchers are deeply involved in teaching and the education of student engineers.
But Gulliver is also very involved with society, through a number of collaborations and original projects. Art/science/popularization projects, like Lutétium, which a doctoral candidate from the laboratory started on YouTube, are created regularly. Finally, Gulliver hosts 2 or 3 international collaborators each year, and the laboratory's researchers are regularly invited abroad.

E.R: The applications are also numerous, especially in soft matter and microfluidics. Several businesses have been created using work carried out in the laboratory. This is the case with Microfactory, which manufactures revolutionary mini-laboratories for cosmetic testing, and PlatOD which is developing a system for producing blood platelets using microfluidics.

HOW THE SUBWAY ILLUSTRATES THE BEHAVIOR OF IONS IN A LIQUID AND MOLECULES IN A GLASS

What do the organization of ions in a liquid and the organization of molecules in a glass have in common? Believe it or not – they share a dynamic which can also be observed in the subway.
When an electric field is applied to a liquid containing ions, the ions are set in motion and an electric current flows through the liquid. To determine the value of the current, the organization of the ions must be known, and to do so, teams from the Gulliver and LOMA laboratories decided to use a "stochastic density functional theory". They have found conductivity results highlighted by physicochemist Lars Onsager in 1927, and calculated the current in a confined system, for example a nanotube. The correlations show that ions tend to line up, just like commuters who naturally line up to quickly make their way in and out of the subway.
Another intriguing example is glass transition. A liquid cooled to a sufficiently low temperature can crystallize and become solid through the periodic arrangement of the molecules it contains. However, when cooled, certain liquids exhibit a dramatic increase in viscosity, to the point of becoming solid, yet without having crystallized – these are glasses. The exact nature of this transition remains unsolved, and continues to resist theoretical analyses. Yet two original series of studies have shed light on part of the mystery.
First, since the 1970s, thin polymer films have been extensively studied as part of experimental projects to observe glass dynamics at the nanometer scale. Researchers from Gulliver proposed to describe this dynamic with a model inspired from Adam and Gibbs's work on glass-transition cooperativity. The idea is simple: molecules in a glass behave like passengers in the subway: confined by their closest neighbors, they can only move cooperatively in a manner that rearranges the whole group. Various molecular dynamics observations and computer simulations have shown that these cooperative regions are



Representation of the cooperative chain that the green molecule can follow to travel within the glass.

organized in random chains. In a thin film, and therefore in the vicinity of a free surface, such a chain is truncated and gains in mobility due to the disappearance of congestion constraints. To put it simply, a subway passenger standing next to the door does not need a cooperative movement to be part of the rearrangement of the train as he leaves it.

On the other hand, the idea of cooperativity, necessary for the structural rearrangements in a glass, can be studied in experiments. These experiments use a model system obtained in the form of a compact stack of vibrated grains. In this case also, the grains are strongly constrained by their neighbors – this time, it appears more like a train station on a busy day. The researchers from Gulliver have shown that the stack reorganization dynamics is intrinsically heterogeneous and intermittent, and that it requires an accumulation of micro-displacements unfolding at the scale of the contacts between grains. The scientists were able to confirm a set of very recent theoretical developments concerning the rules governing the organization of these contacts, and consequently, the rigidity of the glass.

FURTHER READING

The conductivity of strong electrolytes, V. Démery et al., J. Stat. Mech., 2016.
Cooperative strings and glassy interfaces, T. Salez et al., PNAS, 2015.
Experimental evidence of the Gardner phase in a granular glass, A. Seguin et al, PRL, 2016.

IN BRIEF

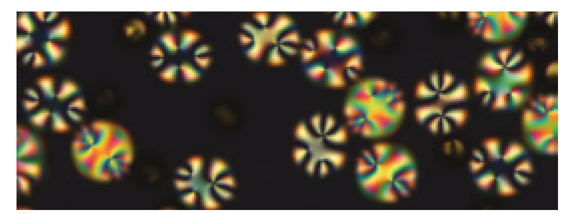
Paper-based blood tests


Paper strips structured with wax channels as blood tests.
© Lutetium Project

Can simple pieces of paper be used as blood tests? Laura Magro, from the MMN team of the Gulliver laboratory, has dedicated her thesis to this topic. Magro has developed a technique to structure different layers of paper by creating wax-based channels. A drop of blood deposited on the paper strip impregnates the paper by capillary forces. The drop then follows one or several paths delineated by the wax, until reaching a screening reagent. Magro was awarded the 2015 L'Oreal-UNESCO "Women in Science" Fellowship for her work on this technique.

FURTHER READING: *Shahnawaz Molla, Laura Magro and Farshid Mostowfi, **Microfluidic technique for measuring wax appearance temperature of reservoir fluids Lab Chip**, 2016, 16, 3795.*

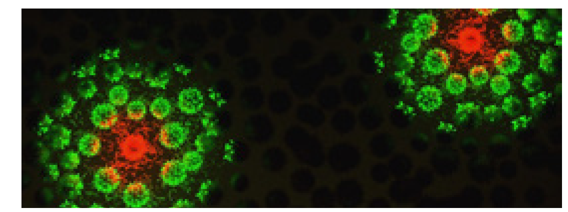
Liquid crystal defects under scrutiny


Different defect structures under polarized light for nematic liquid crystal phases.

Liquid crystals are an incredible class of materials: they flow like liquids, yet their molecules are organized, somewhat like those in a crystal. The team "Collective Effects and Soft Matter" (EC2M) at the Gulliver laboratory focuses on the topological defects created when a liquid crystal is enclosed in a curved surface. In practice, Teresa-Lopez Leon and her students enclose drops of water in a shell of liquid crystals shaped according to the drop of water. The scientists study the defects appearing at the surface – thus far, they have found surprising results. The defects can have a more or less complex structure and evolve between configurations. The study of these defects echoes many problems, such as that of cosmic strings in cosmology, or defects in space-time that are thought to have formed at the beginning of the expansion of the universe.

FURTHER READING: *A. Darmon, M. Benzaquen, D. Seč, S. Čopar, O. Dauchot, T. Lopez-Leon, **Waltzing route toward double-helix formation in cholesteric shells**, PNAS, 2016, 201525059.*

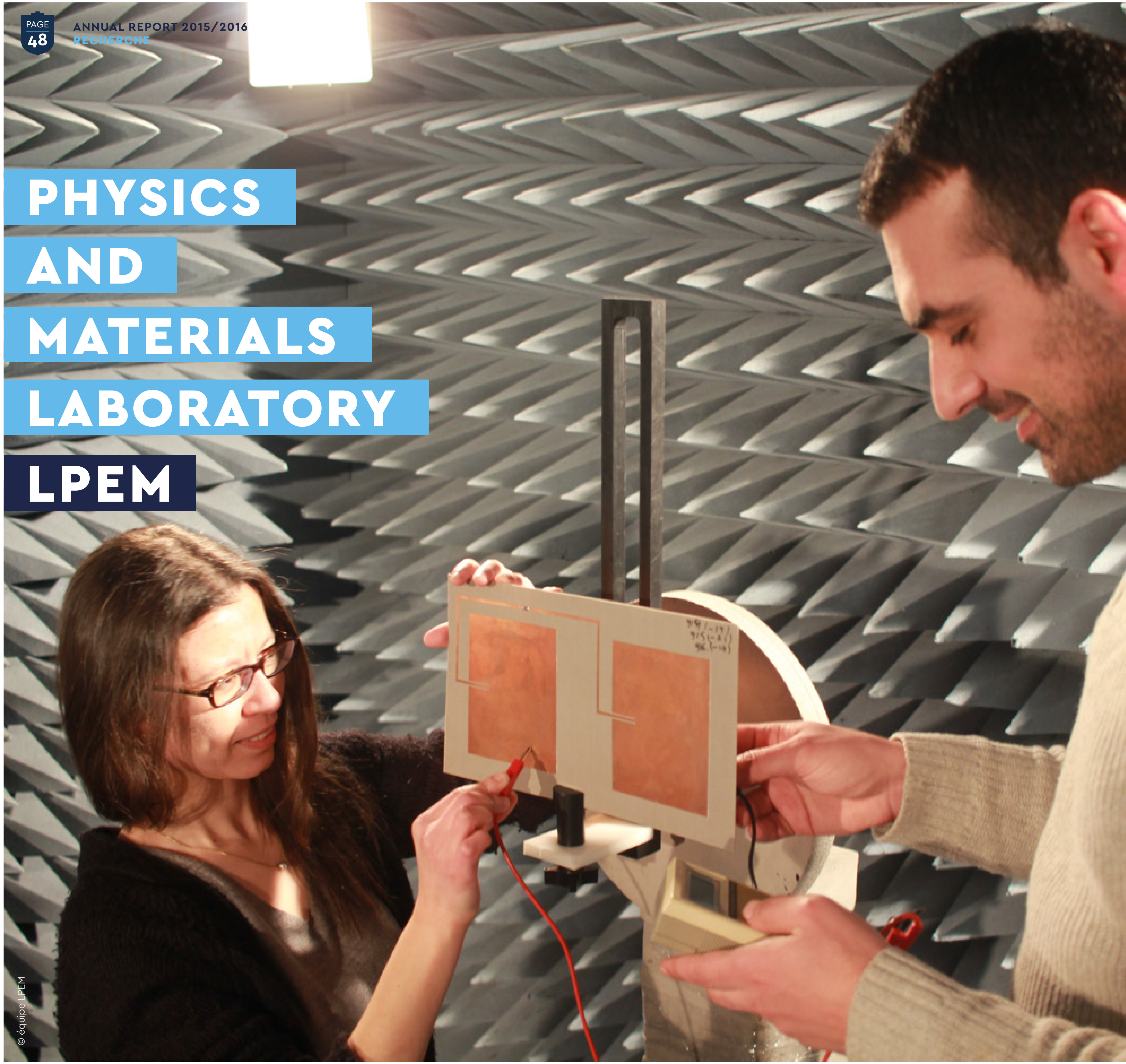
A new team specializing in molecular programming joins ESPCI


Representation of fluorescent molecules equipped with DNA machinery to activate the surrounding molecules.

A new team joined the Gulliver lab in 2015: SPM (Molecular Systems and Programs), which works on molecular programming, directed evolution, and diagnostics. Molecular programming is the science of encoding and processing complex systems on the molecular scale, using molecules as carriers and chemical reactions as computational primitives. This team has already crafted an array of molecular mixtures that reproduces the regulatory network architecture observed within single cells. One of the current goals is to apply this knowledge to the complex problem of enzyme design or to the detection of ultratraces of nucleic acids.

FURTHER READING: *Kevin Montagne, Guillaume Gines, Teruo Fujii, Yannick Rondelez, **Boosting functionality of synthetic DNA circuits with tailored deactivation**, Nature Communications, 2016.*

PHYSICS AND MATERIALS LABORATORY
LPEM



31
researchers

30
PhDs/post-docs

200
articles over the last 3 years

International collaborations
with the US, Canada, China, Japan, Brazil, the UK, Switzerland, Italy, Germany, India and 10 other countries

15 public research contracts,
5 industry contracts and **4** European contracts, including **1** ERC consolidator

PHOTO: Development of hyperfrequency antennas and captors in LPEM's anechoic chamber.

THREE QUESTIONS FOR

RICADO LOBO
Director of LPEM joint research laboratory

Where does the laboratory get its name?

The LPEM stems from the combination of several very diverse thematic units. The subjects we study are so numerous and sometimes so different that the term "materials physics" is still the best common denominator: superconductivity, strongly correlated electrons, confined quantum systems, photonics, photovoltaics, microwave electronics, etc., with an approach that is sometimes fundamental and sometimes oriented towards frankly down-to-earth applications.

What are your research themes?

We have three: on the one hand, we carry out research in fundamental physics, in particular on what is known as quantum matter. Another theme concerns nanostructures, which also has fundamental aspects, like quantum transport, core-shell systems, etc., but also applications including medical imaging.

And the third theme?

This one is much more applied, almost industrial. It entails developing scientific instrumentation: from capacitive flooring enabling fall detection to superconducting wire for electricity transport, to fire detection, to humidity measurement in firewood, all while maintaining a very fundamental aspect, like detection of gravitational waves. We explore a large spectrum *via* three distinct lines and we try to blur the boundaries between these lines.

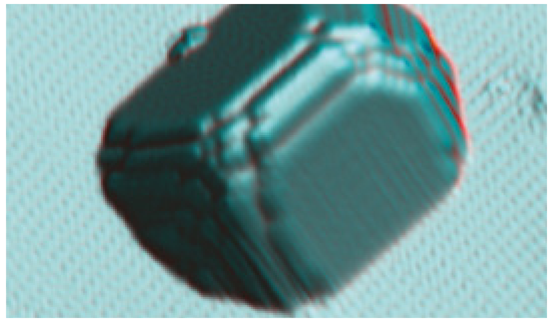
3 BROAD-SPECTRUM AREAS OF RESEARCH

"QUANTUM MATTER"

The frontiers of superconductivity

What is the minimum size for superconductivity to occur in a nanocrystal? In 1959, P.W. Anderson suggested that superconductivity was only possible if the electronic level spacing was lower than the superconducting gap energy corresponding to the binding energy of the Cooper pairs, which are responsible for superconductivity. Until recently, this was a mere conjecture, but now researchers at LPEM have studied the behavior of superconducting lead nanocrystals growing on an indium arsenide surface. They observed that Cooper pairing disappeared when the mean electronic level spacing overcame the superconducting gap energy, thus proving, unambiguously, the validity of the Anderson criterion.

FURTHER READING: ***Superconducting parity effect across the Anderson limit***, *S. Vlaic, S. Pons, T. Zhang, A. Assouline, A. Zimmers, C. David, G. Rodary, J.C. Girard, D. Roditchev, H. Aubin. Nature Comm. 8, 14549 (2017).*



Superconducting lead dot on an InAs substrate.
Each small point in relief is the image of an atom of indium.

Superconductivity in highly diluted electronic systems

A metal is a solid whose electrical resistivity increases with temperature due to the collisions undergone by the electrons. Scattering among electrons is expected to generate electrical resistivity which follows a quadratic temperature dependence. Such behavior has been observed at very low temperatures in a wide variety of metals. Yet, according to the latest observations at LPEM, none of the two most commonly used explanations can justify the persistence of quadratic resistivity in strontium titanate, a diluted metal in which electron concentration can be varied as needed.

FURTHER READING: ***Scalable T2 resistivity in a small single-component Fermi surface***, *X. Lin, B. Fauqué and K. Behnia, Science 349, 945 (2015).*
Critical doping level for the onset of a two-band superconducting ground state in SrTiO3-d, *X. Lin, G. Bridoux, A. Gourgout, G. Seyfarth, S. Krämer, M. Nardone, B. Fauqué and K. Behnia, Phys. Rev. Lett. 112, 207002 (2014).*

"NANOMATERIALS"

Optical applications of quantum dots

"Quantum dots" are nanometer-sized semiconducting crystals. Consisting of between a few hundred to a few thousand regularly spaced atoms, their unique optical and electronic properties that result from their size generate significant interest. More concretely, this gives them fluorescence capabilities: under UV radiation, the dots re-emit in the visible range, with a wavelength that varies according to size. New platelet-shaped nanocrystals developed in the laboratory exhibit unique properties. They will have many industrial applications, including in diodes, flat screens, and transistors.

FURTHER READING: ***Type-II CdSe/CdTe core/crown semiconductor nanoplatelets***, *S. Pedetti, S. Ithurria, H. Heuclin, G. Patriarche, B. Dubertret, J. Am. Chem. Soc. 36, 16430 (2014).*
Electrolyte gated colloidal nanoplatelets based phototransistor and its use for bicolor detection, *E. Lhuillier, A. Robin, S. Ithurria, H. Aubin, B. Dubertret, Nano Lett. 14, 2715 (2014).*

Imaging without background noise

Imaging of living organisms often has limited sensitivity due to high intrinsic tissue fluorescence (known as autofluorescence) which produces background noise covering weak signals, such as those from single, isolated cells. This prevents, in particular, detection of tumor cells circulating *in vivo*. To overcome this obstacle, scientists use fluorescent nanocrystals. These markers emit fluorescence photons 100 to 200 nanoseconds after an excitation pulse, while the autofluorescence of tissues is emitted after 1 to 2 nanoseconds. As a result, a simple "time gate" can be used to detect nothing during the first nanoseconds following the pulse, while recovering the fluorescence with a controlled delay.

FURTHER READING: ***Time-gated cell imaging using long lifetime near-infrared-emitting quantum dots for autofluorescence rejection***, *S. Bouccara, A. Fragola, E. Giovanelli, G. Sitbon, N. Lequeux, T. Pons and V. Loriette, J. Biomed. Opt. 19(5), 051208 (May 2014).*

"MICROWAVE ELECTRONICS AND INSTRUMENTATION"

Testing future superconducting cables

Energy transition comes with a set of challenges – especially in terms of energy transport. As the current system proves inadequate, the European Union launched a project in 2014 named Best-Paths, with the objective to find ways to use the existing networks to support this transition and, when necessary, to improve them. Several technology demonstration projects to increase cable capacity have been launched, including Demo5. The idea is to use a superconducting cable to carry direct current with very high voltage, reducing power loss due to Joule heating. The system is also compatible with very long distances. The only issue is that these cables must be maintained at 30 kelvin (-243 °C) – meaning that the system requires an insulator which, despite its characteristics, is likely to yield under such voltage (320,000 volts). LPEM, a partner in the project, is in charge of developing the method for testing a selection of insulators under real conditions. A test bench with a cryogenic box was built in lab to recreate the extreme conditions in which the cable will be used.

FURTHER READING: ***A Thermomagnetic Mechanism for Self-Cooling Cables, L. De Medici, Phys. Rev. Applied 5, 024001 (2016).***

New fall detection system

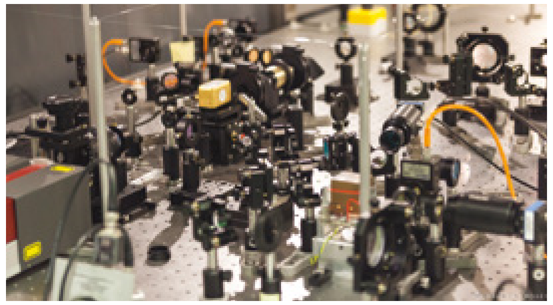
Every year in France, nearly nine thousand people over 65 die from a fall. For those who survive a fall, the longer the person remains on the ground without being able to stand up, the more severe the consequences. As existing systems (badges, video surveillance, etc.) are invasive and limiting, scientists had the idea to equip the floor coverings with capacitive sensors capable of detecting variations in the room's electric field to determine the position of the occupant. The smart components are integrated in the baseboards, making this system both easy to set up and inexpensive. Following an order by company Bostik, the system was developed at LPEM and is currently being tested at the Scientific and Technical Center for Building (CSTB).

FURTHER READING: ***Design of an instrumented floor for detecting falls of people by using capacitive sensors and machine learning techniques***, J. Haffner, thesis defended in 2016.

Gravitational waves detected

On February 11, 2016, the LIGO and Virgo scientific collaborations announced the first direct detection of gravitational waves emitted during the coalescence of a binary system of two stellar black holes. ESPCI is directly involved in this historical discovery as it has been participating in the Virgo experiment for 24 years. Initially, the school was called upon for its expertise in optical metrology, necessary to build Virgo's giant interferometer. Since then, its activity has expanded and researchers from LPEM are now participating in the CALVA experiment in collaboration with the Virgo team at LAL (IN2P3 Orsay). With this technological platform composed of two 5 and 50-meter optical cavities suspended under vacuum, the scientists are exploring new optical techniques for integration into the future generations of Virgo – thermally deformable mirrors, "cooling" of very fine optical cavities, active phase noise compensation in optical fibers, the use of compressed states of light, and more.

FURTHER READING: ***Observation of gravitational waves from a binary black hole merger***, *B.P. Abbott et al. (LIGO Scientific Collaboration and Virgo Collaboration), Phys. Rev. Lett. 116, 061102 (2016).*



Close-up of the CALVA experiment test bench,
on which Virgo's future upgrades are being tested.

BRAIN PLASTICITY UNIT
LPC

© W. Parra

47
people
(excluding interns)

44
publications
in 2015/2016

400,000 memory tests carried out on flies each month

THREE QUESTIONS FOR

THOMAS PREAT
Director of LPC joint research laboratory

How did the laboratory come to be?

The ESPCI Neurobiology Laboratory was created in 1994, at the instigation of Pierre-Gilles de Gennes, who wanted to introduce neurosciences at the school. Its name changed in 2014 to become the Brain Plasticity laboratory. So we are a rather young unit within the school's structure, and I joined in 2006 to develop *in vivo* approaches to brain imaging.

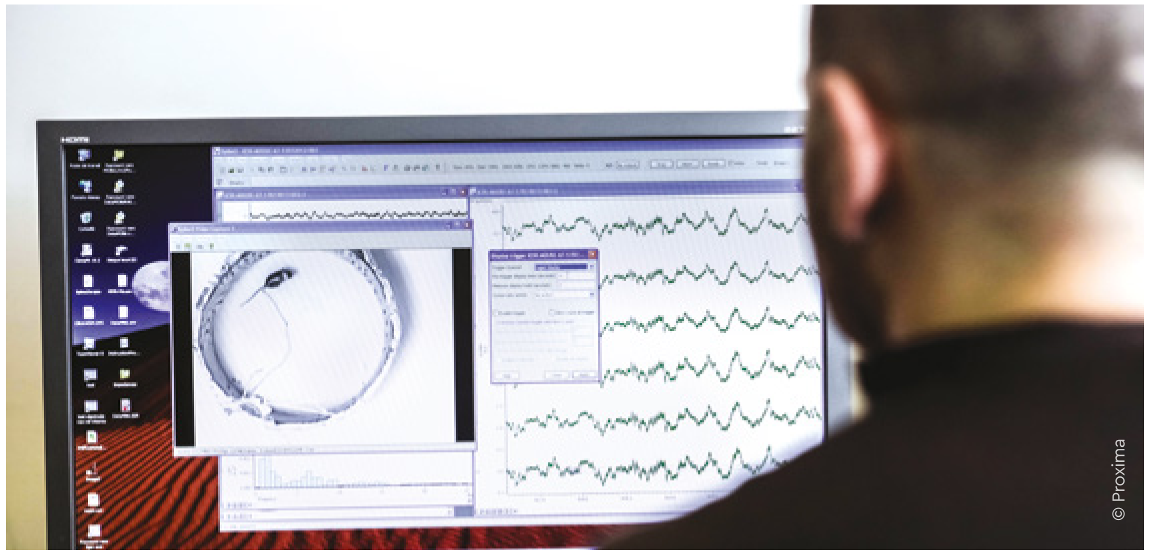
What are the laboratory's overarching themes?

Each team studies two aspects of brain function within their respective fields: a basic aspect that seeks to understand how the brain evolves with experience, fatigue, age, how memory is generated, and a more applied aspect, which studies pathologies of the nervous system: schizophrenia, sleep problems, Parkinson's, Alzheimer's.

How is the unit structured?

Contrary to many research units at ESPCI, we operate in teams with significant autonomy, each with its own research theme, facilities, contracts and students. Two teams are working on Drosophila, two others on rodents, and one on the brain/machine interface – in other words, on human beings. We haven't traditionally had much connection with industry, but that's changing – we've applied for several patents pertaining to the effect of molecules in nervous system pathologies, and developed an industry partnership with Urgotech.

INCEPTION IN MICE



Monitoring mouse brain waves during movement.

The media response to this research no doubt owes much to the film Inception (Christopher Nolan, 2010). The discovery made by Karim Benchenane's team is no less fascinating from a neuroscience research perspective. Following on from their memory research, the team successfully "planted a memory" in the brain of a sleeping mouse.

During a specific sleep phase (not the paradoxal phase, so it can't properly be called a dream), the animal's brain "replays" different trajectories it took during the day. It is therefore possible to follow the place cells as they "discharge" (emit an electric signal) one after another. K. Benchenane's team then had the idea to stimulate the pleasure center at the same instant a neuron connected to a precise place (and not yet associated with a memory) discharged. Once awake, the mouse made its way directly for this location, as if it had already received a reward. The discovery is crucial: on the one hand, it demonstrates (for the first time) the causality between activation of these neurons and spatial memorization. On the other hand, it proves that discharging neurons do indeed correspond to a "revision" of the day's movements. Finally, clearly, it shows that it is possible to provoke relatively complex learning, far more developed than a simple direct response to stimulus, during sleep.

The next step has been identified: they must now test avoidance learning in mice. The team just received funding from the European Research Council for their research. Beyond teaching us more about our brain and how it works, this discovery is proving to have rich implications for the treatment of pathological associations. Perhaps in the future we will be able to teach the brain to dissociate specific memories from negative feelings.

FURTHER READING

Explicit memory creation during sleep demonstrates a causal role of place cells in navigation.
De Lavilléon G., Lacroix M.-M., Rondi-Reig L., Benchenane K., Nat. Neurosci. 2015; 18(4):493–5.

IN BRIEF

Memory and energy

Thomas Preat's team specializes in the study of the dynamics of memory. For a publication in Cell Reports, the team explained in detail the mechanism at work in the formation of appetitive long-term memory in Drosophila. In particular, the team demonstrated that a "sugar" stimulus given to a fly only generated a longterm memory if the insect also received a source of nutritional energy within a five-hour window following the sugar. This research, which connects memory and energy metabolism, follows on from the team's publication in *Science* which demonstrated for the first time that the brain, which consumes a large amount of energy, is capable of carefully regulating its activity in case of scarcity.

FURTHER READING: ***To favor survival under food shortage, the brain disables costly memory.*** *Plaçais P.-Y., Preat T. Science. 2013; 339(6118):440–2.*
Delayed dopamine signaling of energy level builds appetitive long-term memory in Drosophila. *Musso, P.-Y., Tchenio, P. and Preat, T. Cell Rep. 2015; 10:1–9.*

Applied neurofeedback

Cerebral activity monitoring during a cognitive phase.

Traditionally, "neurofeedback" consists of recording brain activity, extracting relevant markers and presenting them in real time to the individual being monitored so they can attempt to interact with them. It can be thought of as simply "physiotherapy for the brain." François Vialatte works specifically on brain/machine interfaces that enable this kind of operation, oriented specifically towards cognitive functions (memory, attention, etc.). The main difficulty is calibrating the machine so that it correctly interprets this information, which varies from one subject to the next. That's where Urgotech comes in, a subsidiary of the group Urgo, which has entered the field of connected objects in medicine. The industry partnership developed with the laboratory aims to develop knowledge about neurofeedback, with several commercially viable applications for Urgotech to boot. For the laboratory, it is the opportunity to better understand how neurofeedback functions (a process that scientists have been probing for forty years), and to use the interfaces developed by the team to demonstrate their effectiveness.

Understanding Parkinson's

Parkinson's disease remains largely misunderstood: though many risk factors have been identified (genetics, exposure to pesticides) and the neurotransmitter dopamine is a confirmed factor in the disease's progression, it is still not clear what triggers it, nor how to treat it. The solution might come from studying Drosophila. Serge Birman's team has demonstrated the involvement of dopaminergic neurons in loss of locomotor response in the insect. More precisely, by making Drosophila express the human protein alpha-synuclein (known to be related to the disease's appearance in humans), the team has been able to identify a smaller group of fifteen neurons responsible for progressive locomotor deficits similar to those experienced by Parkinson's patients. Overexpression of α-synuclein triggers degeneration of their synaptic connections. The research to follow could therefore focus on this sub-group of neurons in order to better understand the origin of the disease and, eventually perhaps, develop an effective shield against these motor symptoms.

FURTHER READING: ***A single dopamine pathway underlies progressive locomotor deficits in a Drosophila model of Parkinson disease.*** *T. Riemensperger, A.-R. Issa, U. Pech, H. Coulom, M.-V. Nguyễn, M. Cassar, M. Jacquet, A. Fiala and S. Birman, Cell Reports (2013), 5(4):952–960.*
A dopamine receptor contributes to paraquat-induced neurotoxicity in Drosophila. *M. Cassar, A.-R. Issa, T. Riemensperger, C. Petitgas, T. Rival, H. Coulom, M. Iché-Torres, K.-A.Han and S. Birman (2015), Human Molecular Genetics 24(1):197–212.*

SOFT MATTER AND CHEMISTRY
MMC

8 researchers and professor-researchers

16 doctoral candidates

11 Post-doctoral students

16 Publications

4/11 Patents published/submitted

THREE QUESTIONS FOR

MICHEL CLOITRE
Assistant Director of MMC joint research laboratory

What are you working on?

The laboratory's research is situated in the field of Soft Matter, at the crossroads of synthetic chemistry, materials science, and polymer and colloid physical chemistry for application in formulation. We custom develop and synthesize new materials using concepts from supramolecular chemistry and reversible covalent chemistry; modify their functions to create property synergies; and study and create models of their rheological, mechanical and optical properties. Our research has strong applied implications and practical prospects that equate to many patent applications and sustained industry partnerships.

What is the laboratory's philosophy?

The Soft Matter and Chemistry lab, arising from a joint research unit associated with industry, cultivates a unique approach that combines basic science, innovations and applications in a single laboratory. Some of our projects are inspired by practical questions posed by our industry partners, while others arise directly from concepts created in the laboratory. In any case, our ambition is to produce internationally recognized fundamental knowledge and to rapidly arrive at tangible applications.

The MMC has produced several incredible applications...

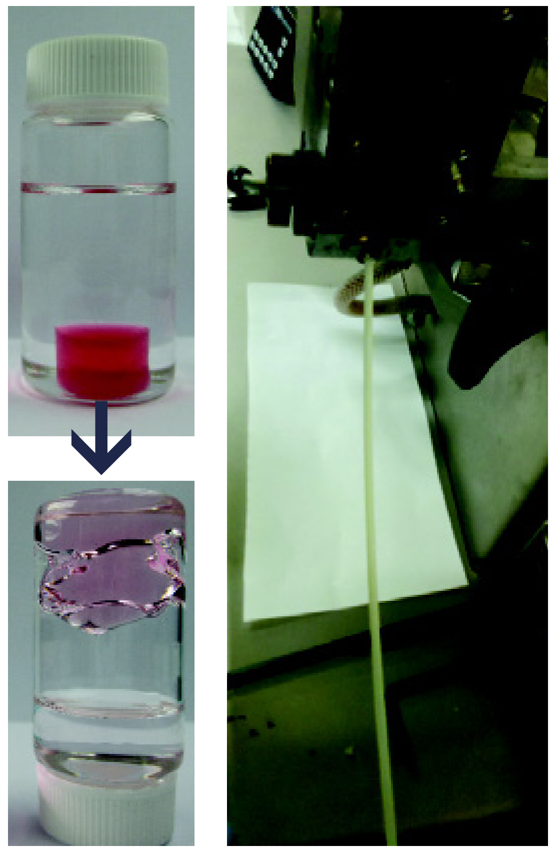
The use and control of dynamic bonds using supramolecular chemistry or reversible covalent chemistry has led to the development of materials with surprising dynamic properties. We were thus able to create a self-healing rubber, a reprocessable plastic that can be worked like glass when hot, a glue for biological gels and tissues, and multifunctional capsules.

VITRIMERS: A THIRD CLASS OF POLYMERS

An outstanding result of the Soft Matter & Chemistry laboratory is undoubtedly the concept of vitrimer. These polymeric materials designed based on research carried out by Ludwik Leibler in 2011 have led to the development of a new distinct category of polymeric materials. Until recently, polymers were divided into two classes with incompatible characteristics: thermosetting resins (insoluble and highly resistant) and thermoplastic resins (capable of softening).

Vitrimer systems are chemical networks containing dynamic bonds, i.e. chemical bonds that have the ability to exchange the atoms they bind while maintaining the number of bonds in the network. The integrity of the material is never questioned, as the atoms remain united regardless of temperature, even though they are not always with the same partner. These bonds are exchanged at a speed dependent on temperature. The macroscopic properties of the materials can be governed by the molecular dynamics of the bonds that constitute the vitrimer network. A vitrimer exhibits the properties of a solid at operating temperature and behaves like a liquid at high temperature, while remaining fundamentally insoluble. The temperature at which this behavior change occurs can be modulated according to the properties and applications targeted by adjusting the dynamics of the exchangeable links.

By combining the insolubility and resistance of thermosets with the softening ability that thermoplastics exhibit under certain conditions, vitrimers constitute a third class that is conducive to all innovations. Crosslinked polymer parts can now be welded, retouched, recycled – and much more.



Left: a methacrylic vitrimer in THF swells, but does not dissolve. Right: a polyolefin vitrimer is prepared and shaped by extrusion.

FURTHER READING

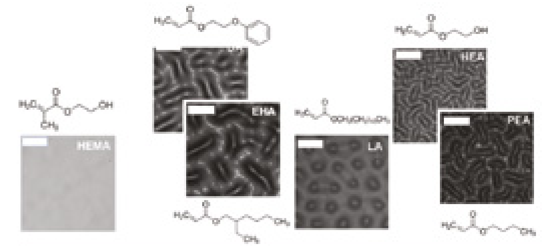
D. Montarnal, M. Capelot, F. Tournilhac, L. Leibler, ***Silica-like malleable materials from permanent organic networks***, *Science 2011, 334, 965–968.*
M. Röttger, T. Domenech, R. van der Weegen, A. Breuillac, R. Nicolaÿ, L. Leibler, ***High Performance Vitrimers from Commodity Thermoplastics through Dioxaborolane Metathesis,*** Science, April 7, 2017.

IN BRIEF

Photopolymerization-controlled auto-texturing of acrylate films

Photopolymerization of acrylate monomers is commonly used by the coatings industry for the production of smooth films. Jérémie Lacombe, a PhD student in the lab, has shown that these same formulations can spontaneously generate textured surfaces under certain conditions. This self-texturing phenomenon is due to the balance between the photopolymerization reaction and the inhibition of the reaction by ambient oxygen. The unreacted monomers make the polymerized film swell, causing surface instability and texturing. The texturings have long-range ordered morphologies whose size and type (hexagons, "peanuts", lamellae) can be controlled with the film thickness, the amount of crosslinker and/or initiator, and the power of UV radiation. This phenomenon is observed in a wide variety of reactive monomers. These results have led to practical applications developed in collaboration with Saint-Gobain.

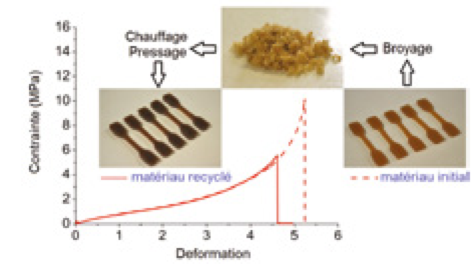
FURTHER READING: *J. Lacombe, C. Soulié-Ziakovic,* ***Controlling self-patterning of acrylate films by photopolymerization****, Polymer Chemistry 2017, DOI: 10.1039/C6PY02072K Illustration.*



Surface textures obtained for various acrylate monomers with increasing reactivity.

Reprocessable natural rubber

Improving natural rubber reprocessing has become a major issue. Usually, these materials are permanently crosslinked by covalent chemistry (using sulfur or peroxides), making any subsequent network modification impossible. During her thesis in the laboratory (defended in 2015), Lucie Imbernon developed an upstream reprocessing technique for natural rubber that uses chemical or physical non-permanent reticulation methods. In particular, she demonstrated the ability of epoxidized natural rubber (ENR) – which exhibits the same mechanical characteristics as its natural parent – to crystallize under stress. However, unlike the latter, the epoxy functions of ENR can be used to crosslink the material with carboxylic diacids, forming exchangeable ester bridges. The result is rubber that can be partially reprocessed, with remarkable self-adhesion properties. Last but not least: unlike sulfur-based vulcanization, the chemistry involved is non-toxic to the environment.



Epoxidized natural rubber reprocessing.
After grinding and shaping, the material recovers mechanical properties close to those measured initially.

FURTHER READING: *L. Imbernon, E. K. Oikonomou, S. Norvez, L. Leibler,* ***Chemically crosslinked yet reprocessable epoxidized natural rubber via thermo-activated disulfide rearrangements****, Polymer Chemistry 2015, 6 4271–4278.*

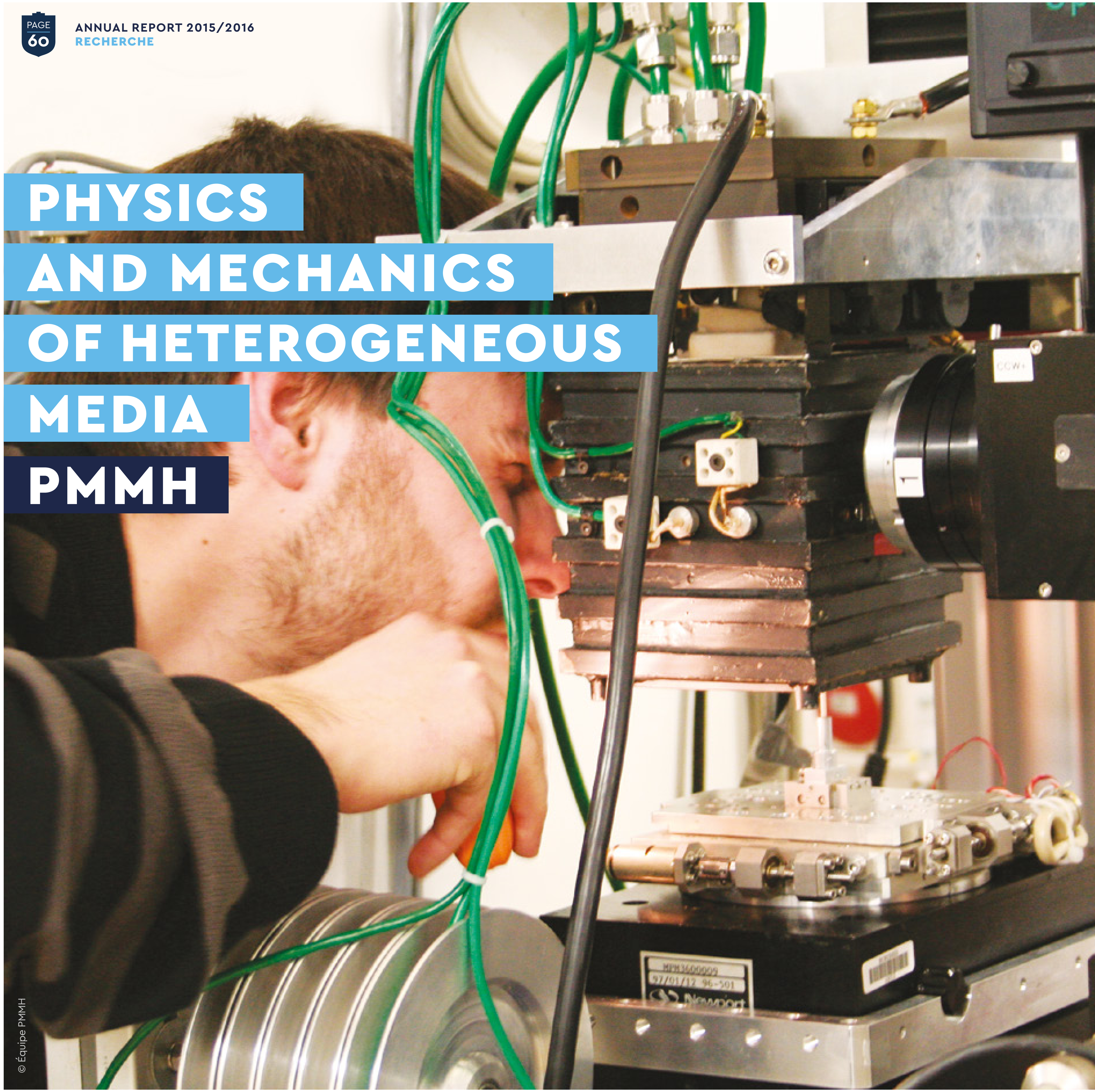
Macromolecules in multi-purpose bottle-brush

"Bottlebrush macromolecules" are objects with a very high molar mass (up to 10 million grams per mole) made of a polymer backbone on which very tight pendent chains are attached. Found in the biological realm, such as in the proteoglycans in cartilages, this architecture can also be synthetically produced. In partnership with the company Coatex, scientists focused on a class of acrylic brush polymers used in the paper industry. Charlotte Pellet, PhD student at MMC, and Michel Cloitre have identified the surprising functions of these bottlebrush macromolecules in colloidal suspensions: water retention, compressive strength, shock absorption, and drying defect inhibition. Pellet was awarded two thesis prizes for her research, which opens many applications, including inkjet printing of ceramics.

FURTHER READING: *C. Pellet,* ***New functionalities of bottlebrush copolymers in concentrated mineral suspensions****, UPMC thesis (2015.*

PHYSICS AND MECHANICS OF HETEROGENEOUS MEDIA

PMMH



70 to 80
publications per year

2.5
publications per researcher per year

Support
CNRS – 21 people
ESPCI – 4 people
UPMC – 5 people
UPD – 3 people

PHOTO: 3D imaging experiment using X-ray microtomography at the ESRF

THREE QUESTIONS FOR

PHILIPPE PETITJEANS
Director of PMMH joint research laboratory

What are the laboratory's areas of research?

Our principal areas of inquiry hinge on fluid mechanics and solid mechanics. Many of the subjects explored in the PMMH laboratory draw on concepts from these two scientific fields: fluid/structure interactions, interface dynamics, wetting, turbulence transition, etc. We also investigate, from a more fundamental perspective, material physics in the vicinity of jamming transitions: rheology of complex fluids, soft matter, vitreous and granular materials, etc. One part of our activity is oriented towards multidisciplinary subjects that borrow investigation methods from biophysics and biomechanics, where many of these concepts result in applications: actin network dynamics, bacterial fluids, hydrodynamics of insect, fish and microrobot swimming, root growth in soil, and more.

How many peole work in the PMMH?

The laboratory includes more than 80 people: 30 permanent researchers and professor-researchers, 7 administrative and technical staff members, around forty PhDs and 6 to 8 post-doctoral students. In addition, we welcome 25 international visitors a year for periods of one week to two months.

You're renown for your experimental activity.

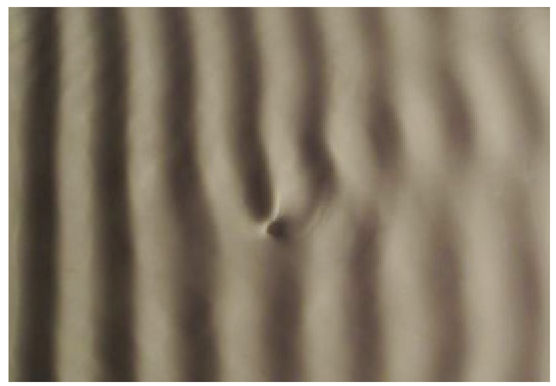
Many experiments, mostly small-scale, are developed to study mechanisms responsible for the behavior of heterogenous media. We are more interested in phenomenology than details. The presence of internationally renown theoreticians is an advantage for the laboratory. This unique identity was built on a large number of very small teams working closely together, as well as with many other teams and researchers in France and the rest of the world. The laboratory has many direct contacts within industry *via* contracts, and indirect contacts *via* ESPCI industry chairs and the school's address book.

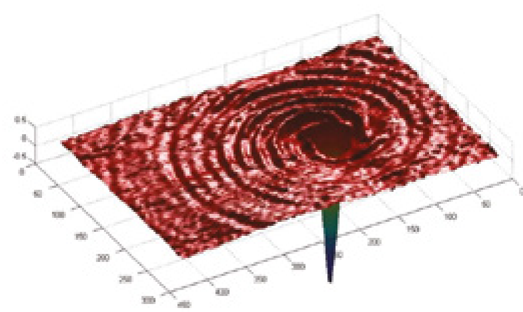
THE PROPAGATION OF SURFACE WAVES

Similar to the Langevin Institute, scientists at PMMH have endeavored to investigate the field of waves, especially the propagation of small wavelengths at the surface of liquids. This type of wave comes with a significant advantage: its speed and wavelength are situated in a range of measures that can be easily accessed using simple laboratory equipment (cameras). The Surface Waves team has developed a system to measure wave fields based on photographies. The scientists can use it to reconstitute the elevation of the wave at the air-liquid interface as a function of time.

More recently, Antonin Eddi has worked on the Faraday instability, a peculiar phenomenon observed by the famous scientist in 1831: the appearance of standing waves on the surface of a liquid agitated vertically under certain acceleration conditions. By studying them closely, Eddi's team observed highly localized vibrations, quite similar to phonons in a crystal system.

Hydroelastic waves are another area of investigation at PMMH. This time, the study focuses on the effects of coupling between a liquid and an elastic film at its surface. The most common case observed in nature is that of ice pack at the surface of the ocean. In such context, the motion of waves is very different from what it would be on a free liquid surface. Although this significant question has already been studied (in floating air projects in particular), surprisingly, it has rarely been considered from an experimental standpoint. With this in mind, scientists at PMMH endeavored to characterize these peculiar propagations and verify the agreement between theoretical predictions and experiments. In so doing, they considered methods for modifying the directions of propagation of the waves, using local variations of the film thickness. Their technique foresees many applications in the future.





Waves propagating on a liquid surface.

FURTHER READING

Experimental demonstration of epsilon-near-zero water waves focusing, *T. Bobinski, A. Eddi, P. Petitjeans, A. Maurel and V. Pagneux, Applied Physics Letters 107, 014101 (2015).*
Faraday wave lattice as an elastic metamaterial, *L. Domino, M. Tarpin, S. Patinet and A. Eddi, Physical Review E 93, 050202(R) (2016).*

IN BRIEF

Active fluids

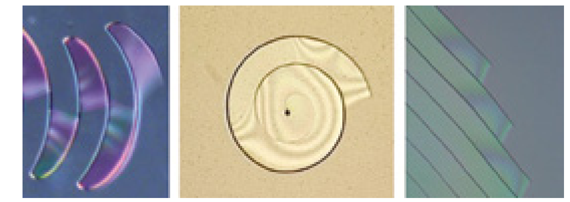
What do bacterial suspensions, bird flights, and schools of fish have in common? They are composed of living organisms equipped with their own mode of propulsion, which leads to specific large-scale behaviors. The team of Éric Clément and Anke Lindner at PMMH is working on suspensions of *Escherichia coli* – a bacterium well known to biologists – this time focusing on their physical behavior. As each bacterium is equipped with flagella, in this particular case, fluid behaviors differ from classical physics, and it reveals unsuspected properties: for example, in the case of canal strangulation, bacteria accumulate downstream from the bottleneck, and not upstream. In a specific range, the fluid even contradicts Einstein's theory – as its viscosity decreases as its concentration increases. All of these studies are of particular interest to industries working on microorganisms, whether for use or protection against them.

FURTHER READING: *Bacterial suspensions under flow, E. Clément, A. Lindner, C. Douarche, H. Auradou , Eur.Phys.J. Special Topics, 225, 2389 (2016).*
Turning bacterial suspensions into a "superfluid", H.M. Lopez, J. Gachelin, C. Douarche, H. Auradou, E. Clément, Phys. Rev. Lett. 115, 028301 (2015).

Nature to the rescue

Biomimicry consists of studying the means developed by living organisms for engineering purposes. Among the many wonders of the animal kingdom, bird flights hold a special place. The team of Benjamin Thiria and Ramiro Godoy-Diana drew inspiration from insect flight to develop new applications: the deformation on insects' wings inspired them to create a new shape for the blades on wind turbines, producing more efficient blades by adapting to different wind regimes. In the field of renewable energies, they have also been inspired by aquatic vegetation to design a "forest" of flexible rods to store energy of waves. It was a double success since this retention reduces the erosive effects on the surrounding coastline, while recovering part of the waves' energy in the form of electric energy.
Less common for ESPCI is the lab's current work on the collective behavior through observation of schools of fish. The scientists have shown how interactions between a fish and its neighbors determine the collective behavior of the school. Another study conducted jointly with the National Museum of Natural History in France aims to characterize the morphological specificities of the head of aquatic snakes to elucidate the contribution of hydrodynamics to the phenomenon of convergent evolution.

FURTHER READING: *Synchronization and collective swimmingpatternsinfish(Hemigrammusbleheri),I.Ashraf,R. Godoy-Diana, J. Halloy, B. Collignon, B. Thiria, 2016, J. R. Soc. Interface 13: 20160734.*
Does aquatic foraging impact head shape evolution in snakes? M. Segall, R. Cornette, A.-C. Fabre, R. Godoy-Diana, A. Herrel, 2016 Proc. R. Soc. B 283: 20161645.



Different morphologies of thin film cracking.

Thin films

Many industries face the challenge of thin film resistance on substrates. After depositing a film on a solid substrate (whether by mechanical, thermal, or any other effect) stresses are known to appear, and can create zones of compression (resulting in blisters) or tension (resulting in cracks). Although scientists considered all the possible forms of these cracks, recent work conducted at PMMH revealed conditions under which singular morphologies appear, such as spirals, "twin bands", or "windscreen wipers". These exotic forms were the subject of a PhD thesis funded through a CIFRE convention with Saint-Gobain. The research team was able to accurately characterize these cracks, and determine the conditions under which they form. Although rare, these conditions are not impossible to recreate, and industries appreciate being able to understand them in details.

FURTHER READING: *A new failure mechanism in thin film by collaborative fracture and delamination: Interacting duos of cracks, J. Marthelot et al., J. Mech. Phys. Solids, 84 (2015) 214–229.*

SOFT MATTER SCIENCES AND ENGINEERING

SIMM

© Équipe SIMM

3
fields:
chemistry,
physical chemistry
and physics
underlie
the laboratory's
interdisciplinary
structure

137
publications

PHOTO : Device for studying deformation mechanisms of elastomers.

THREE QUESTIONS FOR

CHRISTIAN FRÉTIGNY
Director of SIMM joint research Laboratory

How did the laboratory come to be?

The SIMM is the successor to the school's polymer studies laboratory. At the time, the goal was to produce "custom" polymers chemically. In the 1980s, Pierre-Gilles de Gennes and several other researchers came up with the idea that polymer science could be part of a larger vision, that of "soft matter." Following that, we changed the name of the laboratory and added "engineering" because we often work with industry partners.

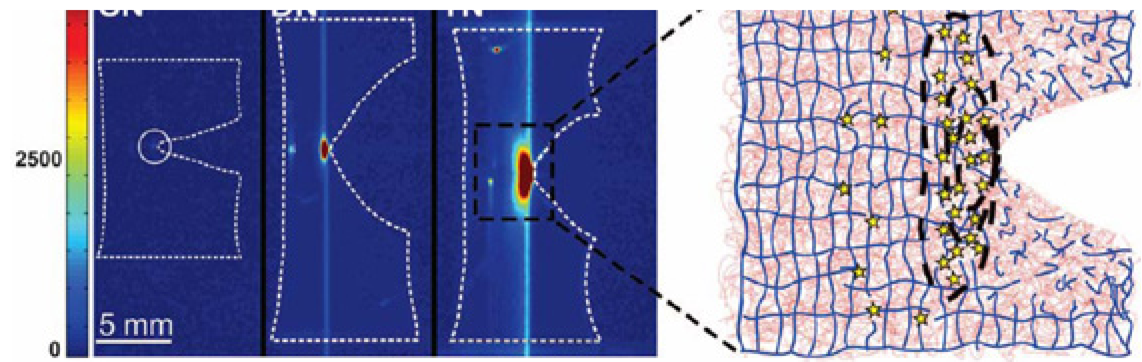
What is unique about the SIMM laboratory?

One of the main ideas is the careful consideration of phenomena at mesoscopic scales: properties of matter often arise from a structure at a scale larger than the atom, but smaller than the object itself. Many mechanical and rheologic properties originate at this scale, including wetness, adhesion, and fracturing, among others. It's very difficult to theorize: we can't simply calculate an average between the molecule and the object. To describe it, conceptual tools like laws of scale have been developed. Today, the field is mature enough to tackle industry-level problems.

Are you currently focused in part on collaborative work with industry?

Yes, but not in the way one might think: we don't directly seek solutions to engineering problems. Companies come to us and we consider, from a basic science perspective, the phenomena they've observed and their empirical solutions. It happens, of course, that we are able to make practical applications, but the core of our activity is primarily basic. One of our success criteria is the number and quality of academic publications co-written with industry research engineers.

ERC GRANT
FOR COSTANTINO CRETON



Mapping and pattern of molecular fracture during crack propagation in an elastomer containing mecano-luminescent molecules.

Every year, the European Research Council (ERC) awards grants to promising researchers who have demonstrated their potential to become leaders in independent research. In this way, the ERC supports the creation of outstanding new research teams.

In 2016, Costantino Creton, CNRS Director of Research in the Soft Matter Sciences and Engineering Laboratory (SIMM) won the highest award for his team's work on fracture mechanisms in soft materials. A peer-reviewed article published with Matteo Ciccotti outlined the project. The goal is to develop as complete an understanding as possible of mechanisms by which energy is dissipated during fracture in soft materials, particularly those with "sacrificial" bonds – in other words, unstable reversible bonds likely to break and reform.

To achieve this, an interdisciplinary team of doctoral candidates, post-doctoral students and permanent researchers with complementary skills in chemistry, physics and mechanics will be established, according to the SIMM philosophy. The research will use a combination of new materials, elastomers and hydrogels containing a variable percentage of sacrificial bonds: mechanical tests will be combined to characterize material rupture and, in particular, crack propagation points. To this end, trials will borrow a technique from biology that has rarely been used with materials: detection using molecules that are mechanophore (for forces acting on the carbon structure of polymer molecules) and mechanoluminescent (for bond rupture), *via* a confocal microscope. Molecular data will be complemented by correlation measurements of digital images (for deformations) and local orientation and damage detection by ray diffusion (visible light and X rays).

The idea has tangible roots: many fracture-resistant soft materials have been developed in recent years by teams of material chemists in laboratories and industry settings alike, in sometimes semi-empirical ways and without a full understanding of the science behind these phenomena. The goal here is to focus on the molecular mechanisms at work to draw conclusions for wider application, in order to guide the development of new materials and propose a multi-scale model of mechanisms that will make them fracture-resistant.

FURTHER READING

***Fracture and adhesion of soft materials: a review**, C. Creton and M. Ciccotti, March 23, 2016, Reports on Progress in Physics, vol. 79, n° 4.*

IN BRIEF

Fluctuations of free surfaces

Since the effects of thermal agitation vary according to the properties of the system under consideration, the latter can be quantified by measuring these effects. About a decade ago, researchers at SIMM developed a simple way of measuring surface fluctuations in soft matter, based on an optical principle. Their technique allows for the detection of waves below a nanometer, with a very wide time dynamic. Scientists use this technique to characterize the rheological properties of an environment without any contact, which opens up a very wide field of applications. More fundamentally, the measurement of surface fluctuations gives access to the properties of highly confined liquid films, on the scale of a few molecules. Finally, it enables the study of the particular dynamics of fluctuations in non-equilibrium systems, such as near the glass transition, for which the fluctuation-dissipation theorem does not apply. The SIMM was recently awarded the Jean Langlois research prize and the instrumentation prize by the Société chimique de France and the Société française de physique for its work on the fluctuations of free surfaces.

FURTHER READING: ***Boundary Condition in Liquid Thin Films Revealed through the Thermal Fluctuations of Their Free Surfaces**, B. Pottier, C. Fretigny, L. Talini, Physical Review Letters 114 (2015) 227801.*

A new path for polymer coatings

Hydrophilic polymer coatings allow for the control of surface properties (wettability, permeability, adhesion, friction, and more), and are of particular interest in materials science, biology and medicine. Although so far, layer-by-layer assemblies (LBLs) and bottlebrush polymers have been used, hydrogel films are emerging as an innovative, stable, versatile, and durable alternative. A simple method to produce crosslinked polymer films in a wide range of thicknesses (from one nanometer to one micrometer) was developed at SIMM. It allows for the growth of various networks on solid substrates, such as hydrogels responding to stimuli, or complex hydrogel films with a targeted architecture (multilayered, inter-penetrated networks, nanocomposite hydrogel films, patterns, etc.). In a microfluidic channel, due to thermal properties, valves or reversible cages can be produced to trap certain molecular objects. This work confirms the relevance of this technology for applications in biology (DNA amplification, single-cell manipulation, microbiology, etc.) at low cost and energy consumption.

FURTHER READING: ***Multiscale surface-attached hydrogel thin films with tailored architecture**, B. Chollet, M. Li, E. Martwong, B. Bresson, C. Fretigny, P. Tabeling, Y. Tran, ACS Applied Materials and Interfaces, 8 (2016) 11729–38. Chollet, B.; D'Eramo, L.; Martwong, E.; Li, M.; Macron, J.; Mai, T. Q.; Tabeling, P.; Tran, Y. **Tailoring patterns of surface-attached multi-responsive polymer networks.** ACS Appl. Mat. Interfaces, 2016, 8, 24870–24879.*

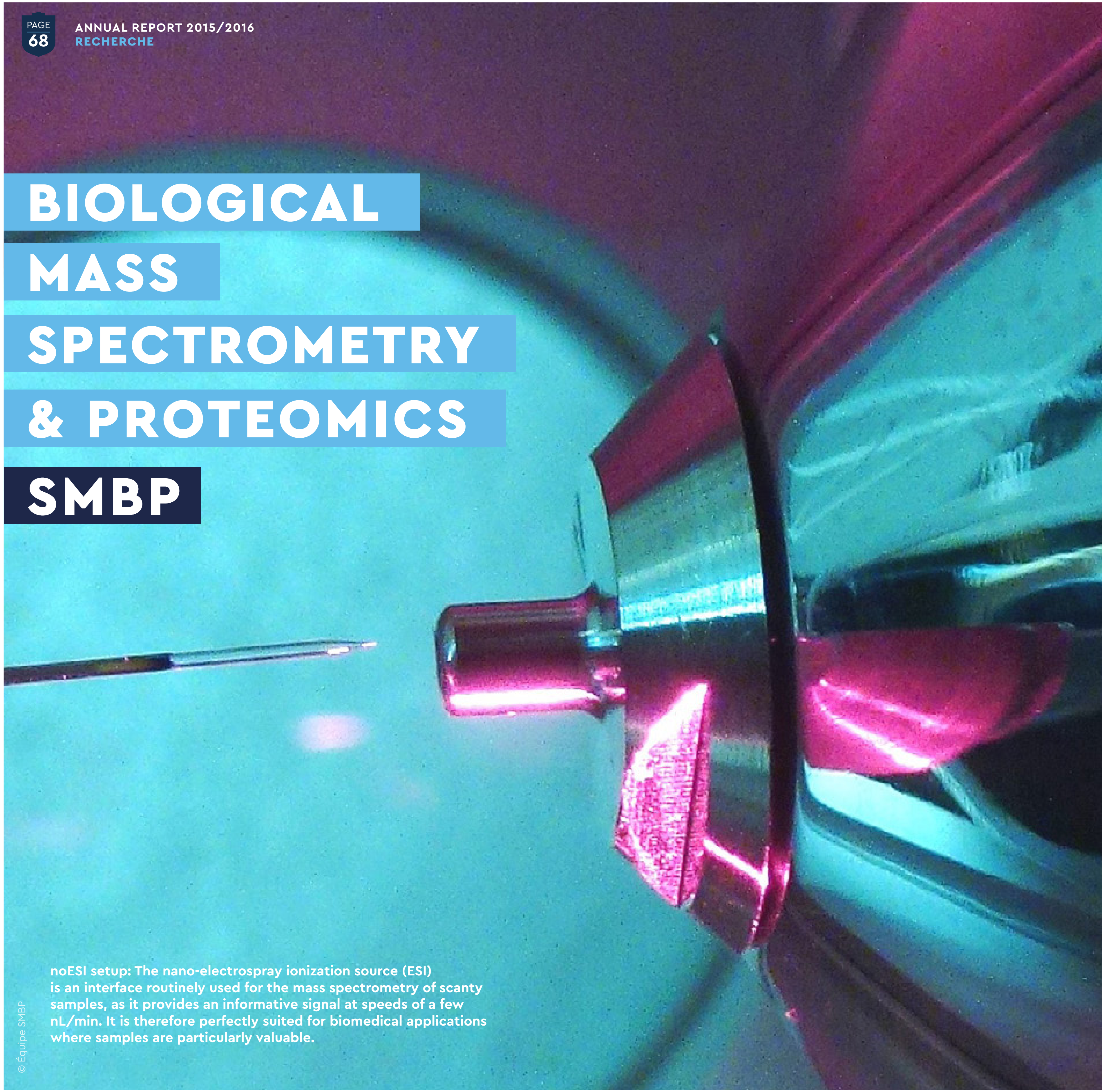
The kinetics of cement finally observed directly

It is known since Le Chatelier that the hydration of Portland cement is initiated by the dissolution of calcium silicate monomers in water, followed by the precipitation of calcium silicate hydrates (CSH) in less soluble layers, in which the silicate ions condense to form short chains. Yet, even after two centuries of widespread use and a century of detailed studies, the molecular mechanisms underlying the kinetic stages of hydration are still debated. The SIMM team used solid-state nuclear magnetic resonance to monitor the hydration of ^{29}Si-enriched Ca_3SiO_5 to determine molecular-level transitional compositions, as well as the interactions between different forms of silicate, hydroxyl groups and water molecules, observed directly for the first time. This work has unlocked a new understanding of this kinetic observed in many systems of silicates. It has also highlighted the interest of Ca_3SiO_5 as a model for studying long-term hydration processes.

FURTHER READING: ***Understanding silicate hydration from quantitative analyses of hydrating tricalcium silicates**, Elizaveta Pustovgar, Rahul P. Sangodkar , Andrey S. Andreev, Marta Palacios, Bradley F. Chmelka, Robert J. Flatt & Jean-Baptiste d'Espinose de Lacaillerie, Nature Communications, 7:10952, DOI: 10.1038,2016.*

BIOLOGICAL MASS SPECTROMETRY & PROTEOMICS

SMBP



noESI setup: The nano-electrospray ionization source (ESI) is an interface routinely used for the mass spectrometry of scanty samples, as it provides an informative signal at speeds of a few nL/min. It is therefore perfectly suited for biomedical applications where samples are particularly valuable.

5 to 6
publications per year

5
permanent positions

4
researcher and professor-researcher contracts

4
PhD candidates

1
technology platform for proteomics and mass spectrometry

10
years of active participation in continuing and professional training (CNRS, Inserm and industry)

THREE QUESTIONS FOR

JOËLLE VINH
Research Director of SMBP joint research and service laboratory

What is the core activity of the laboratory?

The SMBP stems from the ESPCI biology laboratory. It is a recent structure, created in 2009 to meet a growing need in biology that also required a certain know-how in analytical chemistry and separative techniques, specifically super-resolution mass spectrometry. Although only thirteen permanent employees work at SMBP (mostly engineers), more than 100 users work in our lab through multiple partnerships.

Unlike other labs at ESPCI, SMBP is a joint service and research unit *(unité mixte de services et de recherche or USR)*. Can you tell us more?

This type of organization means that CNRS has given us the authorization to invoice services in our field of expertise, which is the identification and characterization of proteins in a sample. But above all, we are a research unit: the services we provide only account for a small part of our activities and fund the maintenance of our equipment.

What are your main research focuses?

Our main area of investigation is at the crossroads between analytical sciences and protein chemistry: we strive to improve sensitivity and specificity to study proteins at the molecular level. How are they expressed? How are they modified? Using mass spectrometry, we are able to analyze the composition of a protein mixture with high accuracy. This proves to be a valuable tool in biology. New disciplines are being developed from these techniques: proteomics, peptidomics, nanochromatography. We work on signaling cascades in response to environmental stresses, such as the redox state and the glycosylation of proteins, which modify their biological functions. The study of post-translational modifications is emerging as a new research theme, which, although I find to be under-investigated, is absolutely essential to achieve a deeper understanding of biological processes, from a fundamental standpoint (immune response mechanism, tissue repair), as much as in biomedical applications (cancer, diabetes, allergy, autoimmune diseases).

SEPARATING PROTEINS FOR IMPROVED RESULTS

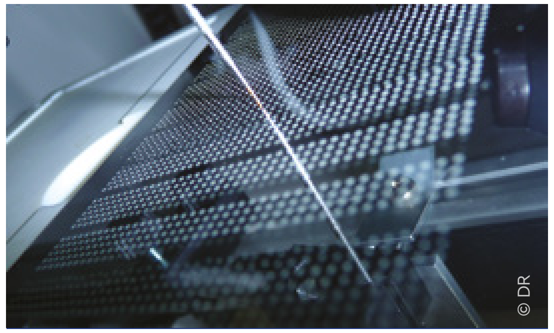
AN IMMENSE POOL OF COMPARATIVE ANALYSES UNRAVELED

The biggest discoveries sometimes follow intriguing paths. A series of research studies on the defense mechanisms used by Drosophila against pathogens was initiated in 2009, first in collaboration with Jules Hoffmann (prior to him receiving the Nobel Prize in Medicine) and then, two years later, with Jean-Luc Imler from the same institute. One of the objectives was to understand the molecular machinery involved in an immune response. After a genetic study, a number of proteins were identified, and the team from SMBP finally completed a comprehensive analysis of these proteins. Their result was a total pool of 369 molecules (corresponding to 291 genes), including 92% with orthologs in humans.

Separating proteins therefore comes as the perfect way to carry out a long series of comparative functional analysis, which are already fruitful. Jean Luc Imler (CNRS), Catherine Schuster (Inserm) and the scientists at SMBP have already observed the role of one of these molecules in virus propagation. This protein, called RACK1, makes the difference between the normal translation of the cell and that of viruses. The latter use RACK1 as an anchor point on ribosomes to propagate and hack the machinery of their host cell. The discovery of this mechanism has created new therapeutic approaches for various viruses (insect virus, hepatitis C, rhinovirus, etc.). For this discovery, the team of scientists was awarded the La Recherche 2015 prize in the Biology category. Who knows what the 368 remaining molecules will reveal?

CUTTING-EDGE EQUIPMENT

SMBP's specificity lies in its technological platform, which is one of the thirteen national Health, Biology and Agronomy Infrastructures (IBiSA) for proteomics. In 2015, fifteen academic teams and three industrial groups used six mass spectrometers running routinely in nanoLC coupling, processed their samples and trained in proteomics with the SMBP engineers.



NanoLCMALDisetup: Chromatography in liquid phase is systematically miniaturized in columns with an internal diameter that does not exceed 75 µm. The separated products are then collected by small robots in fractions of about 40 µL on a Matrix Assisted Laser Desorption ionization (MALDI) target, as shown here, or more conventionally, in coupling with the nanoESI source.

In addition, the CNRS network of the Very Large Research Equipments (TGE in French) of the mass spectrometers with Fourier transform (FT-ICR) is now a research federation (FR 3624) operating in partnership with École Polytechnique and universities UPMC, Paris Saclay, Lille, Rouen, and Lorraine. Recent developments in this area make mass spectrometry a prime analytical tool for the academic research community.

The French teams, equipped with new-generation technology (with magnetic fields between 7 and 9.4 Teslas), make their materials and expertise available to the national and international community to carry out experiments and use the subsequent results (30% of experiment time is available to outside users). The federation is split between seven locations equipped since 2010 – one of them being ESPCI. A permanent tender procedure allows interested researchers to submit their project through a flexible procedure, with minimal response time. Once the application is approved by external experts and when the project coincides with the window booked for experiments, the TGE pays for the costs induced by the analysis by FT-ICR.

FURTHER READING

RACK1 Controls IRES-Mediated Translation of Viruses, *K. Majzoub, M. Lamine Hafirassou, C. Meignin, A. Goto, S. Marzi, A. Fedorova, Y. Verdier, J. lle Vinh, J. A. Hoffmann, F. Martin, T. F. Baumert, C. Schuster and J.-L. Imler, Cell, oct. 1016, j.cell.2014.10.041.*

IN BRIEF

Two outstanding PhDs

Among the outstanding theses defended at SMBP is that of Sophie Liuu, who proposes a new protocol for the classification of amyloses (severe diseases causing insoluble protein deposition in tissues). The method avoids the use of antibodies pre-selected by the anatomopathologist, with a bias-free approach. It increases the efficiency and reduces digestion time (90 seconds instead of 15 hours) using molecular characterization by nano-chromatography coupled with high-resolution mass spectrometry. This approach can be generalized to the study of proteins from raw tissues, whether in the biomedical field or in the agri-food industry.

The laboratory is part of IPGG, and as such, it benefits from micromanufacturing infrastructures for the design of new miniaturized analytical strategies.

Another remarkable thesis was defended by Shakir Shakir, focused on the quantification of post-translational modifications through two new strategies proposed for this domain, which continues to be a challenge for proteomics. Both analytical approaches were applied to the study of cysteine oxidation. The first leads to significant technical improvements and data analysis innovations. The second opens a wide range of applications that can be extended to the study of tissues and biopsies. The strategies developed are now being miniaturized.

FURTHER READING: *Sophie Liuu. Targeted proteomics analysis at high resolution: a powerful tool for the clinical diagnosis from raw amyloid biopsy samples [physics.chem-ph]. UMPC – Université Paris VI, 2014. Available in French.*

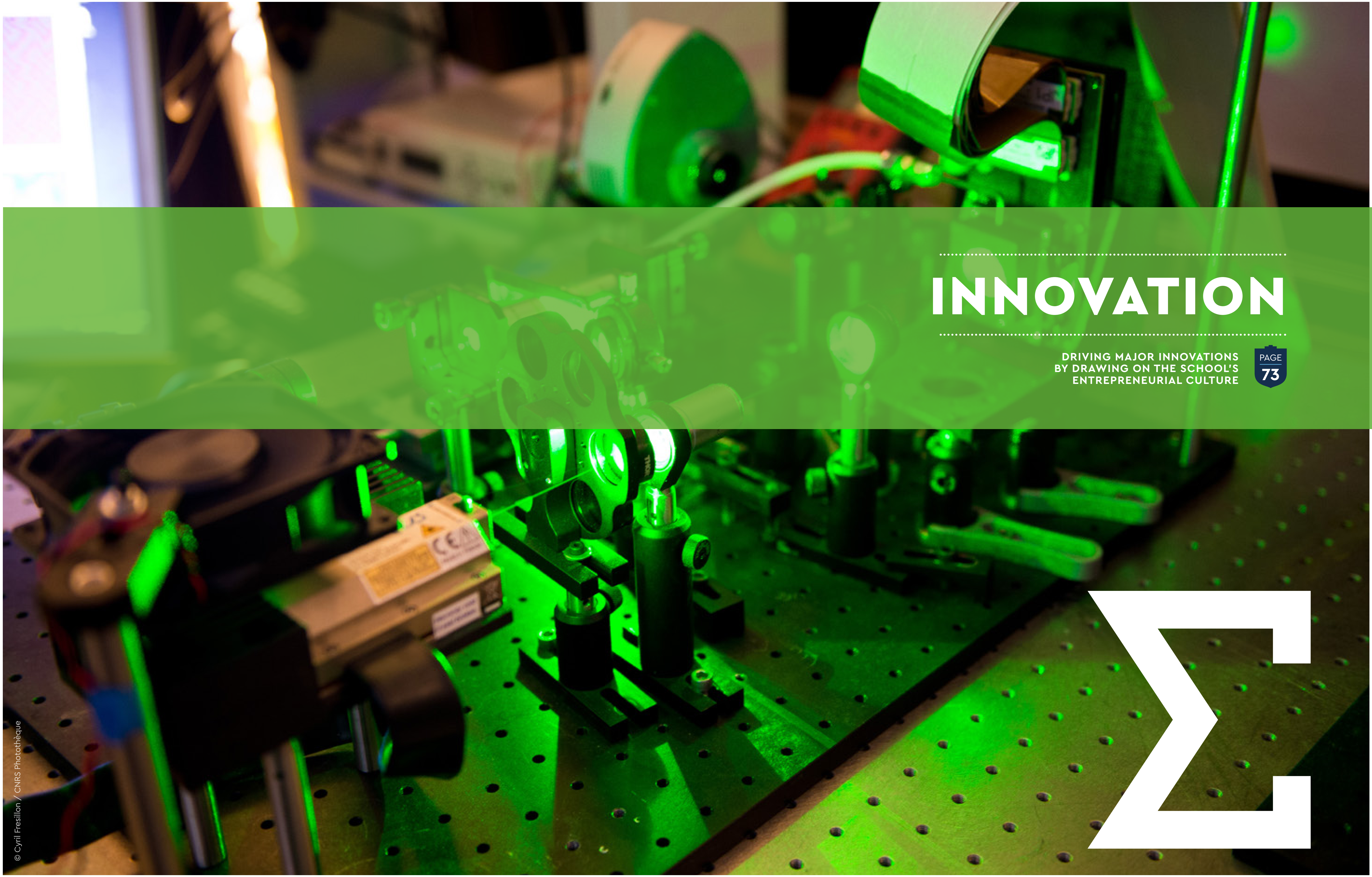
Shakir Mahmood Shakir. Development of new analytical strategies for the molecular characterization of oxidative states at the proteomic scale. *Analytical chemistry. UPMC. Paris VI University, 2015.*

The potential industrial uses of this study are currently being investigated.

A new approach for Tauopathies

Tauopathies are diseases caused by the aggregation of Tau proteins, which are specific molecules in neurons. Sadly, they are most known for their role in Alzheimer's. However, recent studies have shown that localizing the degradation sites of this protein could help better understand the cellular mechanisms causing its aggregation, in particular the N-terminal domain of the protein. The team from SMBP has successfully optimized a proteomic approach to identify a number of new N-terminally truncated Tau species.

FURTHER READING: ***Role of the Tau N-terminal region in microtubule stabilization revealed by new endogenous truncated forms,*** *M. Derisbourg, C. Leghay, G. Chiappetta, F.-J. Fernandez-Gomez, C. Laurent, D. Demeyer, S. Carrier, V. Buée-Scherrer, D. Blum, J. Vinh, N. Sergeant, Y. Verdier, L. Buée and M. Hamdane, Scientific Reports, 14 May 2015.*



INNOVATION

DRIVING MAJOR INNOVATIONS
BY DRAWING ON THE SCHOOL'S
ENTREPRENEURIAL CULTURE

PAGE 73

PAST TO PRESENT: A MULTITUDE OF REVOLUTIONARY INVENTIONS

More than a century after its creation, ESPCI can pride itself on having produced six Nobel Prizes. Great scientific discoveries have emerged from within its laboratories. Here's a look at the inventions of yesterday and today that have revolutionized chemistry and physics, but more importantly, our daily life.

1903

RADIUM

Pierre (professor-researcher) and Marie Curie (researcher) discovered radium and polonium in the ESPCI laboratories in 1898. They won the Nobel Prize in physics for this discovery in 1903.

1907

LUTETIUM

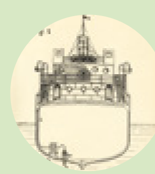
Named as such in 1907 by Georges Urbain, an ESPCI engineer, in homage to the city of Paris (formerly Lutetia), Lutetium, the last element in the lanthanide series, is classified as a rare earth. The isotope ^{177}Lu is used in nuclear medicine for the treatment of certain tumors.

1910

THE NEON TUBE LIGHT

This invention by engineer George Claude, in 1910, marked the beginning of fluorescent color tubes in the field of illuminated signs. George Claude (also the inventor of a process for liquifying air), even purchased the Paz and Silva establishments (household appliances and lighted advertising signs), later acquired by J.-C. Decaux. He founded Air Liquide with his classmate Paul Delorme.

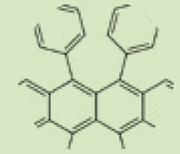
1915



SONAR

During the First World War, Paul Langevin, (professor, then director of ESPCI from 1925 to 1946), developed a machine to detect enemy submarines using the echo of ultrasonic waves bounced off of these objects. Sonar was born.

1917



ANTIOXIDANTS

Rubrene is an antioxidant, a substance that, when added in small does to oxidizable materials, is capable of halting their deterioration. The study of antioxidants, initiated by ESPCI laboratories and the Collège de France around 1917, is still applied to cosmetics and anti-cancer treatments today.

1928

THE BLACK BOX

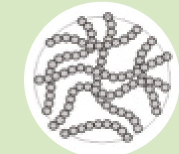
In 1928, while an engineer at ESPCI, Paul Dubois invented an oscillograph capable of recording information in an airplane. This was the origin of the photographic recorder of the Hussenot-Baudouin flight developed in 1939. It was called a "black box" because of its photographic light chamber.

1935

ARTIFICIAL RADIOACTIVITY

Frédéric Joliot-Curie (ESPCI engineer) and his wife, Irène, Marie Curie's daughter, discovered artificial radioactivity in 1935, an achievement that won them a Nobel Prize in chemistry. The applications have been numerous, notably in the field of medical imaging.

1939



MACROMOLECULAR CHEMISTRY

Georges Champetier (41st graduating class) was one of the originators of polymer chemistry in France. The idea of the macromolecule was first proposed in Germany by Hermann Staudinger. In 1939, a conference on macromolecules was organized at ESPCI.

1968

MULTIWIRE CHAMBER

Georges Charpak revolutionized particle detection in 1968 with the multiwire proportional chamber, which replaced the far slower bubble chambers. His elementary particle detectors revolutionized both data processing and medical imaging. His invention won him the Nobel Prize in physics in 1992.

1985

MOLECULAR GASTRONOMY

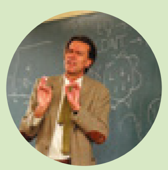
A scientific field in its own right, molecular and physical gastronomy was born in 1985 thanks to Hervé This, ESPCI engineer, and Nicholas Kurti, an Oxford physicist. Working at the crossroads of physics and chemistry, they modeled chemical reactions in cooking (emulsion, flocculation, convection, surfactant effects,etc.).

1990

TIME-REVERSAL MIRRORS

Founder of the Langevin Institute–Waves and Images at ESPCI Paris, physicist Mathias Fink developed, in 1990, a time-reversal technique for sound waves that has found applications in medicine (medical imaging, the lithotrite, brain therapy), submarine detection, and home automation.

1990



SOFT MATTER

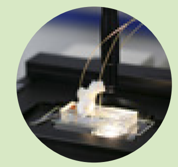
Following in the footsteps of Georges Champetier, originator of polymer chemistry in France in the 1930s, Pierre-Gilles de Gennes received the Noble Prize in physics in 1990 for his research into soft matter (polymers, liquid crystals). In its congratulatory speech, the Nobel Committee referred to the ESPCI director (1976–2002) as the "Newton of our era."

1996

THE INTERNET ROUTER

In 1996, inventor, researcher, professor and entrepreneur Jacques Lewiner, former scientific director of ESPCI (1987–2001), founded the Inventel company, which manufactured the first internet router for France Télécom, the Livebox.

2001



THE MICROFLUIDICS REVOLUTION

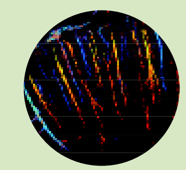
In 2001, Patrick Tabeling joined ESPCI and created the Microfluidics, MEMS and Nanostructure laboratory. He then took over direction of the Institut Pierre-Gilles de Gennes for Microfluidics, a stronghold of the field in Europe, and an institution the school is highly involved in.

2011

VITRIMERS

Ludwik Leibler is a pioneer in polymer physical chemistry. In 2011, he invented a new class of organic materials: vitrimers. These never-before-seen polymer materials, made of polyesters, are insoluble, can be infinitely reshaped, and are recyclable, like glass, but light, elastic and resistant.

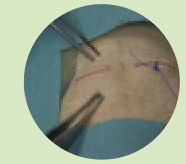
2011



ULTRA-FAST FUNCTIONAL IMAGING

Using ultrasounds, in 2011 Mickaël Tanter developed an unprecedented functional imaging technique with spatial and temporal resolution greater than that of traditional brain imaging techniques. What's more, the technology is non-invasive and portable.

2013



BIOLOGICAL TISSUE BONDING

Ludwik Leibler and his team successfully hastened the closure and healing of deep wounds. In 2013, his team presented a concept of gel and tissue bonding using an aqueous solution of nanoparticles. This bonding method enables tissue healing and regeneration free from inflammation and necrosis.

2015

IDENTIFYING PLACE CELLS

In 2015, by implanting false memories in the brain of a sleeping rodent, Karim Benchenane killed two birds with one stone: he experimented with the concept of inception, but also, and more importantly, identified cells associated with place in the rodent brain.

WIN-WIN PARTNERSHIPS WITH INDUSTRY CHAIRS

Industry chairs serve to ensure that research is carried out in fields that are of primary strategic importance to world economic players. This 4- to 5-year partnership is based on a trio of research, industry and training.

Industrial teaching and research chairs provide privileged partnerships between ESPCI Paris and leading companies Michelin, Total, Saint-Gobain, Axa and Hutchinson. The chairs provide funding for research and education at the school, but are also sources of recruitment and excellence in innovation for industry players, providing a more flexible framework than calls for proposals, for example. Concretely, the program consists of private, tax-exempt donations (up to 60% in compliance with French patronage law) which are used for research and educational programs at ESPCI. Also available are visits to company facilities, conferences, stipends for internships abroad and merit scholarships.

SAINT-GOBAIN CHAIR "MATERIALS SCIENCE AND ACTIVE SURFACES"

Since 2007, this chair, shared with Polytechnique, offers students internships and PhDs in a field with multiple applications: hydrophobic or self-cleaning glass, transparent transistors, thin films for the light systems of tomorrow and photovoltaic development, nanomaterials for electronics and optics.

MICHELIN CHAIR "MATERIALS SCIENCES"

Created in 2008, this partnership promotes and develops research activities centered around the following themes: polymers and composite materials, nanometric structures and mechanical properties of materials, physical chemistry of interfaces and adhesion, tribology, rheology and implementation, aging, multi-level testing and characterization of polymer matrix composites, and modeling of mechanical properties and viscoelastic behavior.

AXA CHAIR "BIOMEDICAL IMAGING"

This chair has been located in the ESPCI Paris Langevin Institute–Waves and Images since 2013. It provides financial support for the work carried out by Emmanuel Fort, professor at ESPCI Paris and creator of the PSE (Scientific Team Project). The chair's goal is to develop new methods of optical imaging to understand cellular mechanisms at the single-molecule level, and the development of new photo-therapies using gold nanoparticles.

TOTAL CHAIR - ESPCI PARIS "ENERGY, CARBON AND ENVIRONMENT SCIENCES"

This chair, inaugurated on September 27, 2010 and renewed in 2016, aims to develop unprecedented, viable technological knowledge and solutions that respect the environment in terms of production, storage, and energy and carbon use. This partnership provides for a series of future projects in favor of education, including scholarships, professional internships, and laboratory resources financed by Total.

DEEP RESEARCH CHAIR DURABILITY OF ELASTOMERS AND POLYMERS

This chair was established between the Hutchinson company, Mines ParisTech and ESPCI Paris on December 15, 2016. Established for a duration of 7 years, it will provide for internships, 7 PhDs and a post-doctoral position. The chair's objective is to understand and predict the lifespan of elastomer and polymer materials developed by Hutchinson for technical applications in the field of transportation (aeronautics, automotive, rail), which are subjected to intense mechanical stresses.

Sanofi and ESPCI sign a patronage agreement

In order to create productive and lasting relationships, ESPCI Paris encourages high-level partnerships in a variety of forms (patronage, research contracts) with companies like Lafarge, Nexans, Total and Schlumberger, to name just a few.

On October 8, 2014, a three-year agreement was signed with Sanofi to accelerate development of future medications using microfluidic systems. The ESPCI and Sanofi teams study, on a large scale and under short timeframes, the risks of possible toxicity related to new medications in development. The first project will involve trials, and their results will optimize the study of drug interactions with human cells (particularly liver cells) in order to prevent undesirable side effects. The goal of the second project is to identify possible benefits of using microfluidic technology in the development or optimization of therapeutic molecule delivery systems, be they chemical or biological, in order to better respond to patient needs.

A mentor for each graduating class

While for the last 15 years, the mentor of each ESPCI graduating class has been a leader in its industry (Total, Areva, L'Oréal, Michelin, Nestlé, Nexans, Safran, Schlumberger), the mentor of the 133th graduating class 2014-2017 is Withings, a start-up created within the school with the help of ESPCI engineer Éric Careel. The year 2015 saw a return to basics with Arkema, an internationally recognized French chemical group. In 2016, Adocia mentored the 135th class. A family company founded in 2005, Adocia is specialized in biotechnology, in particular the development of formulations of proteins for treating diabetes.

Site visits, internship opportunities, recruitment interview simulations, financial aide for certain Student Office activities are all on the agenda.

© OHNK

A SUPPORT STRUCTURE FOR BUSINESS CREATION

Certified by the City of Paris in 2014, PC'up, the ESPCI Paris incubator, has hosted a total of 16 start-ups within its new 600 m² facility located at IPGG and on campus, since 2016.

FROM RESEARCH TO START-UP

PC'up is the fruit of ESPCI Paris' entrepreneurial culture, and has given rise to many start-ups since its creation (three start-ups a year on average). Major discoveries like radium, sonar and more recently ultra-fast medical imaging and self-healing rubber have produced multiple entrepreneurial success stories.

AN INCUBATOR WITHIN A PRESTIGIOUS SCIENTIFIC ENVIRONMENT

"Incubated start-ups are lucky to benefit from the school's existing ecosystem," explains Jean-Baptiste Hennequin, ESPCI Paris general secretary and director of PC'up. One of the incubator's main goals is to develop relationships between ESPCI laboratories and start-ups. Their geographic proximity to the school puts them in constant contact with our 522 researchers and professor-researchers, as well with our students. In addition to project-building support (H2020, PIA 3, etc.), these young companies also benefit from privileged access to leading edge facilities present throughout the school's different sites and the Institut Pierre-Gilles de Gennes (IPGG). This support enables us to respond to the specific research and development needs of start-ups. They benefit from a network of experts within this uniquely innovative ecosystem. PC'up also wants to be space where exchange and conviviality thrive, inviting start-ups to attend lunches with laboratories, thematic workshops and events co-organized with ESPCI and IPGG.

16 START-UPS INCUBATED

Abbelight, Biomillenia, Calyxia, CapTiss, Cardiawave, DNA Script, DropMapp, HiFi Bio, Greenerwave, Inorevia, iSpheres, LOMA Innovation, MicroBrain, Microfactory, Milidrop, PlatOD

PC'UP KEY FIGURES

61 jobs created in 1 year
13 million euros raised
32 patent applications and patent licenses
Multiple prizes: i-Lab, World Innovation Challenge, ScientiStar, Genopole Young Biotech Award, Emergence, MIT Review, Medicen Innovative Business Award

IPGG: AN EXCELLENCE CENTER DEDICATED TO MICROFLUIDICS

Keeping in line with its reputation as an innovative school, ESPCI is a driving force in the creation of one of the world's leading microfluidics institutes, the Institut Pierre-Gilles de Gennes (IPGG). The new scientific field of microfluidics is expected to be revolutionary and promising because it allows for the manipulation of minuscule volumes of fluid (nano-, pico- or femtoliter) using new technology.

IPGG is a 3,000 m² research space located on Rue Jean Calvin in Paris's 5th arrondissement, with a unique technology platform that includes a clean room, a micro-factory workshop, a grey room, a cell culture room, etc. It also comprises four large higher education and research establishments: ENS, Chimie ParisTech, ESPCI Paris and the Curie Institute; 50 industry collaborations and 15 PSL research teams. IPGG is an international excellence center ready to lead the microfluidics revolution, whose industrial applications for the fields of health (early detection of infectious diseases), energy, green chemistry, cosmetics (delicate product gel) and agri-food are considerable.

© W. Parra

THREE QUESTIONS FOR

JEAN-BAPTISTE HENNEQUIN
ESPCI Chief Administrative Officer

What facilitates business incubation within the school?

Freedom at ESPCI has been spared suffocation by bureaucracy, a phenomenon that F.A. Hayek describes so well in The Road to Serfdom, and one that has greatly damaged research in our country. Thanks to the City of Paris, which as support has awarded a great amount of autonomy to the ESPCI administration, there is no towering, over-protective figure that claims to dictate to each researcher with whom and how he or she must file patent applications. At ESPCI, the idea is that researchers freely decide which establishment will develop their inventions. Culturally, researchers at ESPCI are close to the industry with which they enjoy working. Successful entrepreneurial examples have inspired others.

Three start-ups are created each year

Yes, but this pace has picked up in the last three years for two reasons: the short-range "Institut Pierre-Gilles de Gennes in microfluidics" effect that attracts the best start-ups in the field to the ESPCI incubator and the broader "start-up" effect that drives the best scientists and engineers to give it a try. Montagne Sainte-Geneviève boasts one of the densest scientific environments in the world.

What role do these companies play within the school?

Every incubated company has access to the entirety of the school's scientific infrastructure during an incubation period of three years, renewable once for one year. An ESPCI team directly manages the incubator following three original approaches to support:
• Developing relationships between incubated start-ups and school laboratories.
The biggest discoveries arise from serendipitous encounters that ESPCI fosters through key moments between start-ups and scientists.
• Relationships between laboratories and student-engineers and encouragement of student entrepreneurship.
• Support for developing projects based on research-development partnerships between start-ups, industry and public laboratories.

HIGHLIGHTING SCIENTIFIC HERITAGE

PAGE 83

THE LIBRARY: INFORMATION RESOURCES AND HERITAGE

Inaugurated in 1933 by Paul Langevin, the ESPCI Paris library today has a dual mission to document and preserve heritage. The thousands of scientific and technical documents available attract student-engineers as well as French and international researchers. Since 2015, the library has carried out several projects in close collaboration with the PSL Resources and Knowledge Board that coordinates the University Community (ComUE) library network.

A RICH PALETTE OF DOCUMENTARY AND HERITAGE RESOURCES

More than 10,000 full-text electronic reviews published by major scientific publishers (*ACS*, *APS*, *AIP*, *IOP*, *Wiley*, *Springer*, *Elsevier*, *RSC*, *Nature*, *Science*) and databases developed for bibliographic research and bibliometry may be consulted from any computer station at ESPCI and remotely.

The document selection is enhanced by PEB service (interlibrary loan) and by individual article purchase (Pay-per-View). Each year, the library proposes several distance training sessions for students and doctoral candidates to familiarize them with tools for bibliographic research.

The library also houses historic collections of great scientific and cultural value, like the Paul Langevin, Georges and André Claude, Georges Champetier, Pierre Biquard and Pierre-Gilles de Gennes collections. Every year, the archive service established for these collections attracts several French and international researchers who find useful material related to their research work therein.

COLLECT, RESTORE, CONSERVE

Over the last two years, the library has put several cultural projects into place: Director of ESPCI (1905-1925) Albin Haller's diplomas and decorations have been dusted off, restored, flattened and reconditioned; several scientific archive holdings have been treated, sorted, classified and reconditioned [Jacques Lewiner (1943-2001), Jean Rigaudy (1921-2005), Georges and André Claude (1889-1997), administrative archives (1922-2011)].

© W. Parra

In addition, antiquarian books in poor conservation condition regularly receive a special cleaning treatment and new bindings, as has been the case with several dozen books over the last two years.

Finally, the library's historical holdings were enriched by two family donations: a set of 200 photographs by Pierre Biquard, a former student and professor at the school (1965-1971) and archives from Georges Champetier, former student and Director of the school (1969-1976), officially entered the ESPCI Paris collections.

"The library has been a member of the Couperin consortium since 2001."

© DR

Collaboration with PSL

© DR

Since 2015, cooperation between the library and the PSL library network has focused on three missions:

- Subscription sharing. The number of shared subscriptions has constantly increased over the last two years. This has enabled ESPCI to decrease its subscription spending, while enjoying a richer documentary offer.
- Heritage digitization. Following PSL calls for proposals, two heritage document collections from the ESPCI holdings have been digitized and put online: the International Solvay Conferences in Physics; a body of work comprising documents from the Paul Langevin holdings; and a collection of documents from the Georges Champetier holdings.
- Resource labeling. Following a lengthy period of data preparation, carried out in close collaboration with the PSL Resources and Knowledge Board and local computer resources, our documentary resource records (print and electronic) have been reassembled and are now referenced in the PSL Explore Portal. The new portal for our electronic reviews has also created an access point complementary to ESPCI resources. These transformations led to a reassessment of the library website's organization.

PIERRE-GILLES DE GENNES SCIENCE CENTER
DISCOVER SCIENCE DIFFERENTLY

Since 1994, this center has been a unique place where the general public and scientists meet through educational exhibitions, entertaining activities and interdisciplinary events.

In 1994, during his time as director of ESPCI, Pierre-Gilles de Gennes created the Science Center. A space for entertaining the general public and an innovation laboratory for science communication, the Pierre-Gilles-de-Gennes Science Center (ESPGG), renamed as such in June 2007, is located at the crossroads of science, culture, art and society. A middle ground where the general public and scientists meet, it is an open space to encourage exchange, encounters and shared reflection between researchers, teachers, students of any age, journalists, artists, and anyone curious about science and culture. In 2015, ESPGG became an ESPCI Paris-PSL space.


© DR

SCIENCE MUSEUM AND EVENTS SPACE

To highlight the historic heritage and research carried out at ESPCI Paris, and to reflect on both in a science-technology-society perspective, ESPGG commits to increased action through:

- temporary and permanent exhibitions (including one dedicated to Pierre and Marie Curie's original instruments);
- scientific events for family and school groups (like the "Technological Creativity Workshops" and workshops on liquid crystals, extreme cold, sand);
- experimental general public conferences rebroadcast, since January 2015, on the science university's YouTube channel (Unisciel) and on the ESPGG website;
- seminars on scientific communication, pedagogy, responsible research and innovation (RRI) and questions surrounding science and society;
- events, evenings and encounters between art, science and culture;
- projects to support science education in the vein of the La Main à la Pâte foundation (ASTEP program);
- collaborations with student associations like EPICS to offer all audiences close and unusual encounters with the world of research.

Since 2011, the association TRACES (Theories and Reflections on Learning, Communication, and Scientific Education) oversees ESPGG, with the support of the company Les Atomes Crochus, an innovation laboratory for scientific culture.

WHEN ART MEETS SCIENCE

ESPGG approaches art as a tool to construct and question the relationships between science and society. When art examines the world and addresses science and technology, it provokes questioning and reflection in scientists that is worth sharing. Fruitful collaborations are carried out each year with artists from the École nationale supérieure des Arts Décoratifs (ENSAD) and the Collège de France. In 2015, on the occasion of the International Year of Light, ESPGG partnered with applied artist, scenographer and light designer Tom Huet (EnsadLab), who created a work from a prismatic filter that bent and diffracted light, thereby disturbing our interpretation of space. A variation of his work "Comic System" was presented in ESPGG's art-science displays.

ENGAGE WITH KNOWLEDGE

In addition to the general public, ESPGG also targets researchers, industry, journalists, teachers and students who are invited to learn, highlight their work, establish new collaborations, interact with the general public and test their ideas for the future through new living labs. To this end, ESPGG offers training in science communication, including within the framework of the École de la médiation ESTIM; workshops on innovative experiments accessible to the general public (*Instant manips* or Experiment Hour); film screening-debates; discussion days/workshops like Bioart and transhumanism days; round tables and debates between artists, researchers, political leaders, often in connection with events like the festivals Au Quartier du livre, Raccord(s), Imagine Science; or the program "Questions de sciences, enjeux citoyens" (Scientific questions, civic stakes) hosted by the Ile-de-France region. ESPGG is also involved in several European projects focused on education and scientific culture, and occasionally participates in popularizing research projects carried out in PSL establishments.

IN 2015

3,194 events with school groups
115 classes hosted
2,404 general public events
5,000 visitors to temporary exhibitions

Learn more at espgg.org


© DR

ANOSMIA: WHEN OUR SENSE OF SMELL GOES AWRY!

From March 18 to July 31, 2015, ESPGG hosted the exhibition "Anosmia: living without a sense of smell." Through the work of photojournalist Éléonore de Bonneval, some 2,000 visitors had the chance to reflect on their olfactive memory, rediscover memories from childhood and realize the important role they play in their social life. At ESPCI Paris, researchers from the Analytical, Bioanalytical Science and Miniaturization laboratory are trying to develop an analytical strategy to determine the olfactive signature of individuals and establish odor-based identity cards.

50 TEENAGERS THINK ABOUT THEIR BRAIN...

Throughout the 2014–2015 school year, groups of five to eight students from eleven to eighteen years old and their teacher participated in the scientific project "Teenage Brain." Over the course of one to three session, they constantly questioned their own vision of the human brain and its cognitive twists and turns. This work enabled them to reflect on the construction of scientific knowledge, to meet researchers and develop hypotheses. Their combined experimental protocols were presented from June 15 to 27, 2015 at ESPGG.

RESOURCES AND ORGANIZATION

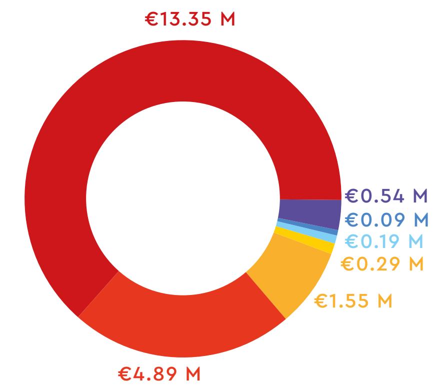
MANAGING A FLEXIBLE AND AUTONOMOUS MODEL
PAGE 89

2016
ESPCI STAFF

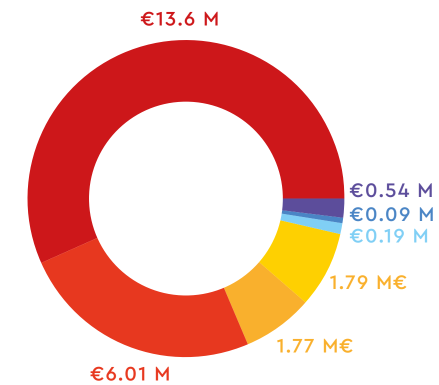
Number of ESPCI employees: **217**
Employees under the age of 25: **11**
Average age: **39 ans**
Number of women: **86**
Percentage of female staff: **39,60%**
ESPCI administrative support and technical employees: **71**
ESPCI professors and senior lecturers: **72**
ESPCI doctoral candidates and post-doctoral students: **65**
Number of ESPCI interns in 2016: **68**

2015-2016
ESPCI BUDGET

DIVERSIFIED OPERATING REVENUE



PB 2015: €20.92 M

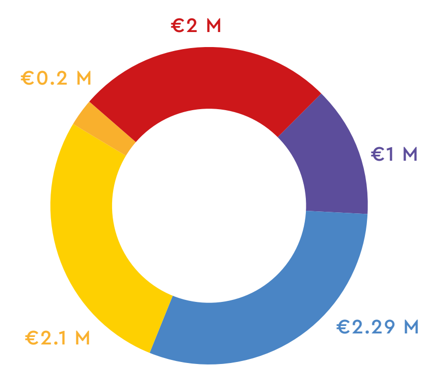


PB 2016: €24.01 M

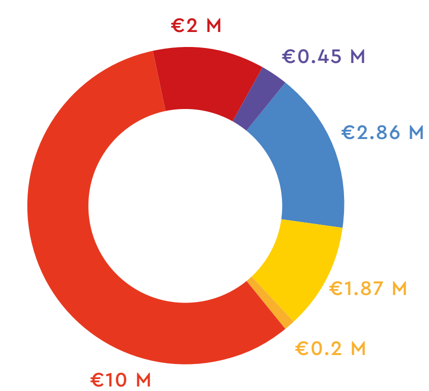
- City of Paris subsidy
- Research contracts
- Amortization of transferable subsidies
- Other resources
- Tuition and admissions fees
- Training levy
- MESR subsidy

Increase in own revenue (+€2.7M), principally maintained by an increase in revenue generated by research contracts (+23%)

INVESTMENT REVENUE MAINTAINED BY THE CITY OF PARIS



PB 2015: €7.61 M

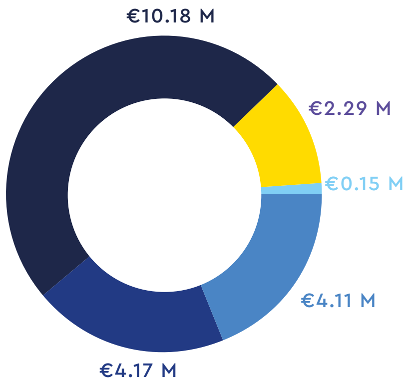


PB 2016: €17.39 M

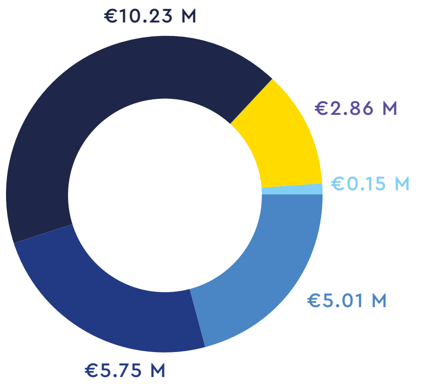
- City of Paris subsidy
- City of Paris subsidy - real estate master plan
- Ile-de-France regional subsidies
- FCTVA
- Fixed asset amortization
- Research contracts

The City of Paris contributed 12 million euros to ESPCI investments in 2016

OPERATING COSTS



PB 2015: €20.92 M

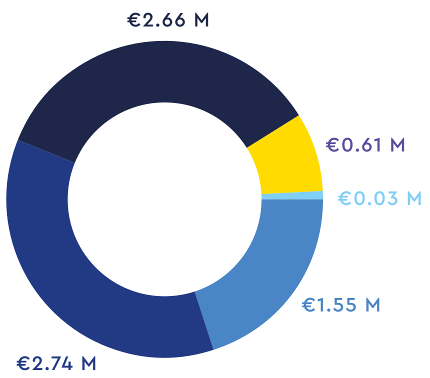


PB 2016: €24.01 M

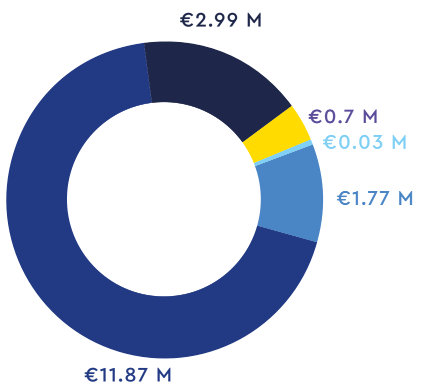
The increase in operating revenue corresponds to a need to finance new operating costs

- Payroll, not including research contracts
- Running cost
- Depreciation and amortization
- Other expenses
- Research contracts

INVESTMENT EXPENSES



PB 2015: €7.61 M



PB 2016: €17.39 M

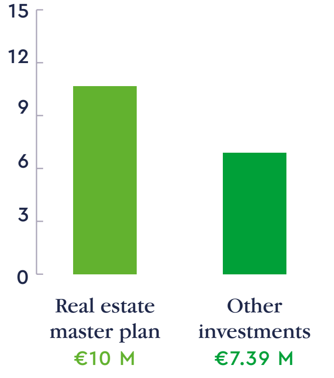
An increase in the investment budget, accounting for the real estate master plan

- Facilities
- Building works, 10 million from real estate master plan
- Amortization of transferable subsidies
- Profit sharing
- Research contracts

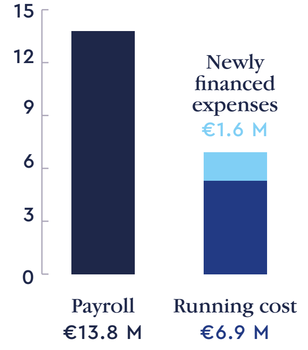
2016
KEY FIGURES

MAIN OPERATING REVENUE

INVESTMENT EXPENSES



KEY OPERATING EXPENSES



Technological research accelerator: **€750 k**
Pierre-Gilles de Gennes Science Center: **€240 k**
Institut Pierre-Gilles de Gennes: **€500 k**
ESPCI Incubator: **€142 k**

ESPCI
SIMPLIFIED ORGANIZATION CHART

BOARD OF DIRECTORS
17 members

PRESIDENT
Marie-Christine LEMARDELEY

INTERNATIONAL SCIENTIFIC COMMITTEE
10 members

INTERNATIONAL RELATIONS
Director
Bénédicte RAVIER

GENERAL DIRECTOR
Jean-François JOANNY

COMMUNICATION DEPARTMENT
Director
Céline RAMONDOU

ADMINISTRATION
Chief Administrative Officer
Jean-Baptiste HENNEQUIN

- **FINANCIAL DEPARTMENT**
  Director
  Céline RISSE
- **DEPARTMENT OF WORKS, MAINTENANCE AND LOGISTICS (STML)**
  Deputy Administrative officer
  Department head
  Ludovic DEHRI
- **HUMAN RESOURCES DEPARTMENT**
  Deputy Administrative Officer
  Department Head
  Florence BOULOGNE
- **IT DEPARTMENT**
  Department Head
  Emmanuel DREYFUS
- **ESPCI INCUBATOR**
  Management and organization
  Manon POMMIER
- **EUROPEAN DIVISION**
  Manager of European Projects
  Lucie EBRAN

SCIENTIFIC RESEARCH DEPARTMENT
Director
Rémi CARMINATI

- **LIBRARY**
  Supervisor
  Catherine KOUNELIS

9 JOINT RESEARCH UNITS (UMR)
1 FEDERATION OF EXPLORATORY RESEARCH (FRE)

Langevin Institute (UMR 7587)
Dir.: Arnaud TOURIN

Gulliver (UMR 7083)
Dir.: Elie RAPHAËL

Physics and Materials Studies (UMR 8213)
Dir. : Ricardo LOBO

Physics and Mechanics of Heterogeneous Media (UMR 7636)
Dir.: Philippe PETITJEANS

Sciences & Engineering of Soft Matter (UMR 7615)
Dir.: Christian FRETIGNY

Soft Matter & Chemistry (UMR 7167)
Dir.: Ludwik LEIBLER

Chemistry, Biology & Innovation (UMR 8231)
Dir.: Jérôme BIBETTE

Brain Plasticity (UMR 8249)
Dir.: Thomas PREAT

Biological Mass Spectrometry & Proteomics (USR 3149)
Dir.: Joëlle VINH

Paris Porous Material Institute (FRE 2000)
Dir.: Christian SERRE

DEPARTMENT OF ACADEMIC PROGRAMS
Dean
Véronique BELLOSTA

- **ADMISSIONS DIRECTOR**
  Sophie NORVEZ
  REGISTRAR
  1st year Sophie PEZET
  2nd year Nicolas LEQUEUX
  3rd year Philippe NGHE
  4th year Anne DEVULDER
- **INDUSTRY RELATIONS MANAGER**
  Brigitte BEAUSSART

* UMR: UNITÉ MIXTE DE RECHERCHE (JOINT RESEARCH UNIT)
FRE: FEDÉRATION RECHERCHE EN EXPLORATION (FEDERATION OF EXPLORATORY RESEARCH)

BOARD OF DIRECTORS

DESIGNATED ADMINISTRATORS

President
Ms. Marie-Christine Lemardeley
- Paris City Council Member
- Deputy Mayor, oversees higher education, student life, research

ADMINISTRATORS WITH DECIDING VOTE
(in alphabetical order)

Mr. Edmond Amouyal
- Representative of the Ministry of Higher Education and Research

Ms. Florence Berthout
- Paris City Council Member
- Mayor of the 5th arrondissement

Mr. Armel de la Bourdonnaye
- Representative of ParisTech
- Director of the École Nationale des Ponts et chaussées

Mr. Jean Chambaz
- President of UPMC Sorbonne
- Professor of cellular biology at the Pierre-and-Marie-Curie Faculty of Medicine

Ms. Sandrine Charnoz
- Paris City Council Member
- Council Member for the 12th arrondissement

Mr. Yves Contassot
- Paris City Council Member
- Council Member for the 13th arrondissement

Ms. Alexandra Cordebard
- Deputy Mayor, in charge of academic affairs, educational success, academic schedules

Mr. Sylvain Gilat
- President elect of ESPCI Alumni

Mr. Didier Guillot
- Paris City Council Member
- Council Member for the 18th arrondissement

Ms. Béatrice Lecouturier
- Île-de-France Regional Council Member
- Paris City Council Member
- Council Member for the 16th arrondissement
- Commissioner to the Mayor of the 16th arrondissement, in charge of higher education

Mr. Franck Lefèvre
- Paris City Council Member
- Council Member for the 15th arrondissement
- Doctor-engineer with the Defense procurement agency (DGA)

Mr. Jean-Louis Missika
- Paris City Council Member
- Council Member for the 12th arrondissement
- Deputy City Mayor, in charge of urbanism, architecture, Grand Paris projects, economic development and attractiveness

Ms. Rachel-Marie Pradeilles-Duval
- Assistant director of training and occupational integration
- Representative of the Directorate of Higher Education and Occupational Insertion (DGESIP/MENESR

Mr. Didier Roux
- Director of Research and Innovation laboratory for the Saint-Gobain Group

Mr. Thomas Tiennot
- Student-engineer from the 134th graduating class (2nd year)
- President elect of the Student Office

PARTICIPATE WITH ADVISORY STATUS

Mr. Jean-François Joanny
- General Director

Ms. Véronique Bellosta
- Dean of Academic Programs

Mr. Rémi Carminati
- Dean of Scientific Programs

Mr. Jean-Baptiste Hennequin
- Chief Administrative Officer

GUEST EXPERTS (ELECTED)

Mr. Nicolas Lequeux
- ESPCI professor in the Physics and Material Studies joint research laboratory
- Teacher Representative

Ms. Mathilde Reyssat
- Senior lecturer in the Gulliver laboratory
- Teacher Representative

Mr. Richard Dara
- Laboratory assistant
- Administrative and Technical Staff Representative

Mr. Guillaume Sarfati
- Student-engineer from the 132nd graduating class
- 4th-year Student-Engineer Representative

Mr. Lucas Sixdenier
- Student-engineer from the 133rd graduating class
- 3rd-year Student-Engineer Representative

Ms. Meriem Bensouda Koraichi
- Student-engineer from the 134th graduating class
- 2nd-year Student-Engineer Representative

Ms. Line Holtzer
- Student-engineer from the 135th graduating class
- 1st-year Student-Engineer Representative

ESPCI CHSCT MEMBERS

PRESIDENT

Marie-Christine Lemardeley

STAFF REPRESENTATIVES

Yacine Oussar
- UCP-UNECT union member

Camille Sauvage
- FO union member

Christian Beaugrand
- UCP-UNECT union deputy

ADMINISTRATIVE REPRESENTATIVES

Jean-François Joanny
- ESPCI Director

Jean-Baptiste Hennequin
- Chief Administrative Officer

Ludovic Dehri
- Work, Maintenance and Logistics Department Head (STML)

Matthieu Carel
- STML

Adeline Favier
- Human Resources Department (SRH)

Matthieu Buard
- Workplace Safety and Prevention Department (SPST)

A SCIENTIFIC COMMITTEE OF INTERNATIONAL SCALE

Since 2007, ESPCI has been endowed with an International Scientific Committee (CSI) that annually presents the Board of Directors with a written report of the school's teaching and research activity and possible new directions. Members of the CSI are appointed for a 6-year renewable term. ESPCI Paris belongs to the small number of establishments of higher education and research that have proven themselves capable of gathering an exceptional team, able to lead an global and insightful vision for the institution's major scientific and educational policy orientations.

PRESIDENT

Prof. Michael Cates

- **Lucasian Professor of Mathematics at the University of Cambridge**
- **Fellow of the Royal Society (FRS)**
- **Fellow of the Royal Society of Edinburgh (FRSE)**

A theoretical physicist specialized in soft matter, Mike Cates is known for his work on polymers, colloids, surfactants, bacterial suspensions and granular media.

MEMBERS FROM ACADEMIA

Prof. Jian Ping Gong

- **Professor at the Laboratory of Soft & Wet Matter at Hokkaido University, Sapporo (Japan)**

A specialist in polymers and new polymer-based materials (hydrogels, etc.), Jian Ping Gong studies the physical and biological properties of these innovative materials.

Prof. Laura H. Greene

- **Physics professor at Florida State University**
- **Chief Scientist at the National High Magnetic Field Laboratory**
- **Professor of physics at the University of Illinois at Urbana-Champaign**

An experimenter in condensed matter physics, Laura Greene investigates strongly correlated electron systems and new materials.

Prof. Édith Hamel

- **Professor, Department of neurology and neurosurgery, Montreal Neurological Institute and Hospital, McGill University (Canada)**

Neurobiologist Édith Hamel studies the interactions between astrocytes, neurons and microvessels.

Prof. Dr. Georg Maret

- **Professor, Soft Matter Physics, University of Konstanz (Allemagne)**

Physicist experimenter Georg Maret specializes in both soft matter and light propagation in disordered media.

Prof. Amos B. Smith III

- **The William Warren Rhodes Robert J. Thompson Professor of Chemistry, Department of Chemistry, University of Pennsylvania (États-Unis)**
- **Member, Monell Chemical Senses Center, Philadelphia**
- **Associate Director, Penn Center for Molecular Discovery**

Organic chemist Amos Smith develops new synthesis methods, including for the synthesis of molecules with pharmacological applications.

Prof. Samuel I. Stupp

- **The Board of Trustees Professor of Materials Science, Chemistry, & Medicine, Northwestern University (United States)**
- **Director, Institute for BioNanotechnology in Medicine**

After working in polymer chemistry, Sam Stuff turned to investigating regenerative medicine. He works on biomedical applications for supramolecular materials.

MEMBERS FROM INDUSTRY

Dr. Armand Ajdari
Vice-President of Research and Development at Saint-Gobain (France)

Dr. Éric Carreel
President-Founder of the companies Inventel, Invoxia Sculpteo & Withings (France)

Dr. Helen Routh
Vice President, Strategy & Innovation, Philips (Boston, United States)

AN IMPROVEMENT COMMITTEE TO SUPPORT EVOLUTIONS IN EDUCATION

Each year, the Improvement Committee takes a careful look at certain teaching units, grouped by discipline, as well as global aspects of educational policies at the suggestion of the Department of Academic Programs. These reports are transferred to the International Scientific Committee.

The Improvement Committee is overseen by the Dean of Academic Programs and includes:

• 6 representatives from the Teachers Committee (3 professors and 3 senior lecturers), elected by their peers and renewable by thirds (one professor, one senior lecturer) every 4 years.

• 6 student-engineer representatives (at least one per year), elected by their peers from among the classes present at the school.

• 6 external members (4 leading figures from industry and 4 from academia), appointed for 4 years by the General Director, at the suggestion of the Dean of Academic Programs.

EXTERNAL MEMBERS

MEMBERS FROM INDUSTRY

Ms. Dominique Baude (102th)
Director of New Products at Essilor International

Mr. Lionel Breton (89th)
President and CEO of ForceA

Ms. Bernadette Charleux
Deputy Director of Research and Development at Saint-Gobain

Mr. Bertrand Demotes-Mainard
Director of Thales Research & Technology (TRT)

MEMBERS FROM ACADEMIA

Mr. Sergio Ciliberto
Director of CNRS research at the physics laboratory at the École normale supérieure in Lyon, President of the Improvement Committee

Ms. Agnès Benassy-Quéré
Professor at the Université Panthéon-Sorbonne, President of the Economic Analysis Committee (CAE)

Mr. Ludovic Jullien
Professor at UPMC and in the department of chemistry at the École normale supérieure in Paris

Mr. Alain Prochiantz
Professor at the Collège de France, member of the Académie des sciences (French Academy of Sciences)

TEACHERS' COMMITTEE REPRESENTATIVES

Ms. Annie Colin
Professor with the Sciences and Engineering of Soft Matter Laboratory

Mr. André Klarsfeld
Professor with the Brain Plasticity Laboratory

Mr. Marc Fermigier
Professor with the Physics and Mechanics of Heterogeneous Media Laboratory

Mr. José Bico
Senior Lecturer with the Physics and Mechanics of Heterogeneous Media Laboratory

Ms. Alice Pavlowsky
Senior Lecturer with the Brain Plasticity Laboratory

Mr. Jérôme Vial
Senior Lecturer with the Analytical, Bioanalytical Sciences and Miniaturization Laboratory

The Dean of Academic Programs (Véronique Bellosta) and the year's representatives (Sophie Pezet 1Y, Nicolas Lequeux 2Y, Philippe Nghe 3Y, Anne Devulder 4Y) also serve on the Improvement Committee. Other external experts may be called upon to serve if necessary.

ESPCI Paris – Communication Department – April 2017 – Photos: W. Parra-ESPCI – Graphic Design: Hélène Mulot

ESPCI PARIS

ÉCOLE SUPÉRIEURE
DE PHYSIQUE ET DE CHIMIE INDUSTRIELLES
DE LA VILLE DE PARIS

10, rue Vauquelin, 75231 PARIS CEDEX 05
+ 33 1 40 79 44 00

espci.fr

PSL RESEARCH UNIVERSITY PARIS

MAIRIE DE PARIS