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agence d'évaluation de la recherche
et de l'enseignement supérieur

Section des Unités de recherche

Evaluation report

Research unit :

Laboratoire P.A.S.T.E.U.R - UMR 8640

Ecole Normale Supérieure de Paris



march 2009



agence d'évaluation de la recherche
et de l'enseignement supérieur

Section des Unités de recherche

Evaluation report

Research unit :

Laboratoire P.A.S.T.E.U.R

Ecole Normale Supérieure de Paris



Le Président
de l'AERES

Jean-François Dhainaut

Section des unités
de recherche

Le Directeur

Pierre Glorieux

march 2009



Evaluation report)

The research unit :

Name of the research unit : Laboratoire P.A.S.T.E.U.R

Requested label : UMR

N° in case of renewal : 8640

Head of the research unit : Mr Christian AMATORE (next Head: Prof. Ludovic JULLIEN)

University or school :

Ecole Normale Supérieure de Paris

Other institutions and research organization:

CNRS

Université Paris 6

Date(s) of the visit :

02 et 03 mars 2009



Members of the visiting committee

Chairman of the committee :

Mr Richard G. COMPTON, Cambridge University, UK

Other committee members :

Mr Allen J. BARD, Austin University, USA

Mr Patrick MAESTRO, Université de Bordeaux , FRANCE

Mr Luis ORO, University Zaragoza, SPAIN

Mr Peter ROSSKY, Austin University, USA

Mr Ahmed ZEWAİL, Caltech University, USA

CNU, CoNRS, CSS INSERM, représentant INRA, INRIA, IRD...) representatives :

CoNRS representative, Mr François GUILLAUME



Observers

AERES scientific representative:

Mr Pascal DUMY

University or school representative:

Mr Yves GULDNER, ENS

Mrs Florence BABONNEAU, Université Paris 6

Research organization representative (s) :

Mrs Gilberte CHAMBAUD, Directrice Scientifique CNRS

Mr Francis SECHERESSE, DSA CNRS



Evaluation report

1 • Short presentation of the research unit

- Numbers of lab members: 32 including 10 researchers with teaching duties (5 Paris 6, 1 Paris 4 (IUFM) and 4 ENS including 5 PR and 5 MC), 17 full time researchers (10 DR CNRS and 7 CR CNRS), 5 ITA (5 ETP) including 1 engineer CNRS and 4 IATOS (4 ETP) To these numbers must be added because of administrative reasons 4 ITA CNRS whose role is devoted to administrative or workshops tasks related to the whole Department of Chemistry and not only to UMR 8640.
- Numbers of HDR: 18;
- Numbers of PhD students who have obtained their PhD and average length of a PhD during the past 4 years: 19 with 18 publishers. Numbers of PhD students currently present in the research unit: 24 ;
- Numbers of lab members who have been granted a PEDR: 2;
- Numbers of “publishing” lab members: 29, i.e., all researchers (27 with or without teaching duty) and 2 ITA CNRS associated to researches.

2 • Preparation and execution of the visit

The committee visited the unit over 2 days in March 2009, having previously been sent full, clear and appropriately detailed documentation describing the unit and its activities over the period for evaluation. At the start of the visit various presentations were received covering the organization, structure, finances and scientific work of the unit. Ample time was then provided for in depth discussions with the scientists of the unit and for visits to the various laboratories. The committee also met usefully with (a) UMR council and (b) CNRS, ENS and UPMC representatives. Overall the organization of the site visit was exemplary and the team has a high degree of confidence in its findings.

3 • Overall appreciation of the activity of the research unit, of its links with local, national and international partners

The unit is characterized by highly innovative interdisciplinary science of an internationally leading quality with high impact and visibility. Although the work is diverse it is coherent and synergistic with scientific benefit at all levels from that of team leader to graduate student. There are wide and diverse international and local collaborations (*vide infra*) of both academic and industrial character. All teams were fully integrated into the laboratory strategy so that overall the Unit activities are more than the sum of the individual team efforts.

The financial management of the unit is transparent and fair. There is excellent vision and forward planning to ensure continued excellence allied to the recruitment of first rate scientists at all levels. Appropriate efforts were apparent for outreaching activities and the promotion of science in the broadest sense.

A team by team analysis follows before some general conclusions and recommendations.



4 • Specific appreciation team by team and/or project by project

Team 1 : Molecular Electrochemistry and Activation

The team is a world class and leading group across a remarkable diversity of science: organometallic mechanisms, applications of ultramicroelectrodes to interfacial chemistry in the broadest sense and electrochemistry applied to a range of biological problems including exocytosis and oxidative stress. Interplay of rigorous fundamental science with real and novel problems is a particular feature of the group. The group has a unique and wide expertise across a breadth of areas ranging from applied mathematics through the design of state-of-the-art electronics to the manipulation of sensitive biological systems at the single cell level. This group has wholly pioneered the area of organometallic electrochemistry with a clear impact on the field. Similarly the biological measurements provide a totally innovative approach, which is increasingly impacting classical biology.

Scientific quality and production

The research area of molecular electrochemistry and activation is well defined and is constituted by three areas, with 14 researchers with a tenure position, 14 researchers who do not have a tenure position and two technicians. The experimental and conceptual approaches are original and relevant to current important research problems. The team shows excellent productivity, 102 publications, most of them in high impact journals, 56 invited conferences and keynote lectures, one book and three book chapters. The impact at the international level is very high as evidenced by the very high number of citations (a total of 11,766 citations to the group leader) and invited presentations at high visibility conferences.

Recognition, attractiveness, and integration in the environment

The molecular electrochemistry and activation team is recognized internationally as a leading laboratory in this field and is very visible by all the usual criteria for defining scientific excellence. The team members receive frequent invitations to lecture in international conferences across all three subareas of the group; many invitations are for plenary lectures. Two members of the group are Editors of well-known international journals, as well as members of numerous editorial boards. The leader of the team has received numerous prizes and has been very active in the creation of research collaborations at the international (CNRS lab Xiamen) and national level (Federation of Physico-Chemical Sciences for Analytical Sciences). A highly successful collaboration with a team of Ukrainian applied mathematicians has been synergistic. The team has been able to attract good researchers and enseignants-chercheurs from a wide background of institutions, as well as from ENS graduates.

Strategy, leadership and laboratory culture

The strategy of the group is based on the application of electrochemical methods to a wide variety of chemical and biological problems. The team leader has shown remarkable vision in the development of the group on all time scales, ranging from the long term to the immediate future. His vitality is reflected in the dedication and enthusiasm of a highly effective team. The teams have also worked effectively with industrial enterprises and produce a constant flow of doctoral students who have gone on to independent scientific careers.

Appreciation of the projects

The track record of the group over the last 4 years demonstrates a remarkable degree of innovation and external recognition. The quality and quantity of output is exceptional given the modest resources available. A diverse range of future projects were outlined which are likely to result in science of the highest impact, particularly if the group is provided with resources at the level of their international competitors. For example, this laboratory is the leading one in the field of fast electrochemical measurements that depend heavily on the design and construction of instrumentation. It is important that a staff position (engineer) in the area of electronics is made available to the group to support these efforts.



- **Strong points:** Outstanding recognition, productivity and interdisciplinary approach, world class research in the application of ultramicroelectrode techniques, especially in the field of biological, single cell, studies and organometallic electrochemistry.
- **Weak points:** Lack of instrumentation and technical support in electronics, marginal laboratory facilities.
- **Recommendations:** Additional technician (engineer) for instrument development, larger budget for modernization of instrumentation.

Nom de l'équipe : Molecular Electrochemistry and Activation

Note de l'équipe	Qualité scientifique et production	Rayonnement et attractivité, intégration dans l'environnement	Stratégie, gouvernance et vie du laboratoire	Appréciation du projet
A+	A+	A+	A+	A+

Team 2 : Theory

Scientific quality and production

The theoretical component of the UMR is focused on the addressing condensed phase chemical processes. The importance of this area is evident, when one recognizes that it includes most traditional chemical processes, as well as all of those of importance in biological chemistry and modern materials chemistry. It is completely clear that the development of advanced theory and modeling algorithms is an essential step for understanding, predicting, and eventually engineering, such processes when one considers the simple fact that essentially every *experimental* lab has adopted the mature basic tools developed by theorists during the past few decades in order to guide their experiments.

The performance of theorists over the past four years has been quite remarkable, continuing the consistently high level of impact that the group leader had established over many years. The work is important in more than one area, including mechanisms in biophysical systems, reactivity that is important for atmospheric science, and theory relevant to interpretation of a variety of spectroscopic probes. The total number of publications and invited presentations is exceptionally high for a group of only two permanent researchers.

Recognition, attractiveness, and integration in the environment

This research thrust is very widely known in the chemical community broadly, well beyond the theoretical community, as evidenced by the 45 invited talks reported during the period. The editorial positions held by the group leader also demonstrate the high level with which his work and judgment are respected. He maintained a group of excellent students during this time.

Strategy, leadership and laboratory culture

The theory component of the UMR has evolved a great deal over a short time. This evaluation takes into account the fact that the completed work of the past quadrennial that is attributable to the UMR is due to the past group leader and one permanent researcher, while the group going forward on the projects will include, in addition to that permanent researcher, three theorists who were either not attached or only briefly attached to UMR 8640 during the completed quadrennial period. Nevertheless, the substantial contributions of the new theorists over the past four year period do serve as a rational predictor, providing confidence in the future performance of these individuals. All four theorists are internationally known in the theoretical community, with the younger individuals somewhat less widely known, due to their relatively more recent entry into the community as independent researchers.



The theory group formed in the UMR, with the additional independent researchers, represents a truly outstanding assembly of modern theorists working at the recognized frontiers of theoretical chemistry. This group is highly notable for expanding the traditional national scope of theoretical chemistry beyond the traditional focus on quantum chemistry. The formation of a nucleus of excellent individuals in one laboratory, all working in the condensed phase area will provide substantial added value, being a highly visible center internationally, comparable to the best group in this research area in Western Europe. The new structure, as a collection of scientifically and intellectually independent but well connected individual programs, follows the highly productive style of the University of Cambridge and the leading US universities, and it is to be commended. The governance by a rotating administrative head will assure that all groups remain scientifically strong. This structure is a forward looking organization that will provide sustainability of this theory center.

It is worth noting that these groups have acquired a very substantial state-of-the-art computational facility with grant funds. Such facilities provide computational power at a much higher level than individual “desktop” machines, but also require maintenance at a professional level comparable to an advanced spectrometer. However, at the present time, no support for such an individual appears to be in place. The result is that this maintenance falls to the senior scientists in the group, an inefficient and costly use of their time. The provision of, at minimum, a half-time technician for this maintenance role would be an excellent investment.

Appreciation of the projects

The proposed projects in the Pôle on Theoretical Chemistry encompass novel and important efforts that are at the leading edge of developments globally. The focus on multiscale modeling, mixed quantum-classical methods, electronic excited states, ionic liquids, and advanced spectroscopies are positioned very well to lead research on an international basis. They also reflect the unique character of this group, including, in every case, a genuine element of theoretical development in addition to computational modeling. Specifically, these research projects will directly address aspects of materials research in directed self-assembly and material structure and properties more broadly, as well as addressing both biological and biomimetic systems. In addition, the projects directly address questions of importance for technologies needed for sustainable energy and for chemical synthesis in a sustainable environment.

An important contributor to the impact of the projects is the visibility of the work, and these projects will be no exception. In this regard we wish to point out our satisfaction that the emeritus status of the former group leader has been demanded by the UMR PASTEUR and reviewed favorably by the CNRS Comité National and the Direction of the Institut de Chimie of CNRS. We understand that it follows presently a long administrative process in CNRS Headquarters. This status, though formal, will help retaining the group’s public status and its international visibility, while the visibility of the younger members continues to mature.

As a final note, this theoretical group has a great deal of expertise in the area of liquids, liquid interfaces, and spectroscopy. The integration of these individuals into the new theoretical thrust on confined liquids, described in the project for FR 2702, would be an ideal addition to the success of the next quadriennial for the SFR.

- **Strong points:** Modern focus on key issues in condensed phase chemistry. Exceptional publication and invited lecture record. Critical mass of faculty and students now developed to generate synergy.
- **Weak points:** Insufficient computational support staff requires senior investigators to divert valuable research time to this task. Focus needed to maintain current global visibility in the future, both short- and long-term.
- **Recommendations:** The funding of a technician to maintain the group computer clusters is needed to reach the potential of the group. Facilitate the appointment of the former group leader to Emeritus status to ensure short term visibility.



Nom de l'équipe : Theory

Note de l'équipe	Qualité scientifique et production	Rayonnement et attractivité, intégration dans l'environnement	Stratégie, gouvernance et vie du laboratoire	Appréciation du projet
A+	A+	A+	A+	A+

Team 3 : Systems Chemistry

Scientific quality and production

The team "Systems chemistry" is composed of 3 permanent researchers and 3 technicians/engineers (1 is shared with another group of the unit). The main research activity during the past 4 years was dealing with the design, the synthesis and the analysis of systems that can reproduce complex chemical/biological behaviors. The key concept of this group is the "property-directed synthesis". Within the frame of such strategy the group has developed theoretical approaches as well as unconventional experimental tools in order to acquire dynamic parameters necessary for the theoretical analyses. Indeed these new analytical developments are highly original, for example the design of an epifluorescence microscope coupled to a microfluidic device in which an electric field (static or periodic) can be applied, for example for sorting a given reactant submitted to a titration reaction. Thermodynamic and kinetic parameters can be extracted in a selective way for the reactant of interest in a mixture of components. Theoretical investigations and promising experimental results have also been obtained on filtering the kinetic response to temperature modulations.

In total the achievements in research and educational duties of the team are impressive; 29 papers were published in very good journals (J.Am.Chem.Soc., Phys. Rev., Angew. Chem. Int Ed, J.Phys.Chem etc.), 13 books for students were written and the senior team members are deeply involved in administrative tasks (Director and vice-Director of the chemistry department at ENS).

Recognition, attractiveness, and integration in the environment

Due to the originality of the theoretical and experimental approaches, the notoriety and the attractiveness of the team are very high. As a matter of fact excellent talented young researchers are joining the group for the next contract. The novelty of the scientific achievements and the involvement in education tasks are also remarkable.

Strategy, leadership and laboratory culture

The project of the team to create a pôle in biophysical chemistry is ambitious and promising. It relies on the expertise and the talent already well established in the group "Systems Chemistry" and on that of prominent young scientists, a physicist from Rennes and a chemist from another laboratory in Paris. The overall goal of this pôle is to reinforce the current activity of the laboratory in biological/biophysical chemistry and to share instruments and methods to get a structure with a critical mass in a highly competitive area. Internal and external collaborations already exist or were initiated recently that make the project meaningful and promising. Perhaps the project should specify more precisely its position within ENS and its expected contribution to the activity of other groups (transverse programs) in the laboratory.

Appreciation of the projects

This pôle in biophysical chemistry at ENS will be nucleated by setting up several research axes, in particular (among other projects) dealing with the triggered renaturation and assemblies of proteins (artificial photoactive chaperones), tailored magnetic nanoparticles to modulate cellular components, systems pharmacology or the analyses of chemical networks by temperature modulation. Clearly the projects of this new team are ambitious and realistic given the well established expertise of its members.



In conclusion this is an excellent team that brings novelty and originality in its combined theoretical - experimental approach for studying complex chemical and biochemical systems. The assignment of means (allocation of new surfaces, financial support) to the new incoming researchers must be a priority for the next quadrennial.

- **Strong points:** Originality of the methodology that combines theory and unconventional analytical tools for solving key problems in complex systems. Excellent scientific productivity and worldwide recognition. Attractivity.
- **Weak points:** Better visibility needed for the future pole.
- **Recommendations:** The assignment of significant means to the pôle and to the new incoming researchers must be a priority.

Nom de l'équipe : Systems Chemistry

Note de l'équipe	Qualité scientifique et production	Rayonnement et attractivité, intégration dans l'environnement	Stratégie, gouvernance et vie du laboratoire	Appréciation du projet
A+	A+	A+	A	A+

Team 4 : Microfluidics, Chemical organization, and Nanotechnology

The group "Microfluidics, Chemical organization, and Nanotechnology" started 4 years ago and has very rapidly developed a significant activity in microfluidics applied to life sciences

The team, although very small (two permanents) is very complementary. They work with 10 PhD students (5 co-tutored with China) and 2/3 post-docs. They are very open to collaborations, both with their local scientific environment (ESPCI, Curie, INSERM, .but this should be better structured at the Paris scale, see in the recommendations) and worldwide (China, Japan, Italy, ...).

They have developed their activity around the use of microfluidics to address problems linked to life sciences. They have developed particularly very clever means to produce capillary controlled surface organisation, on-chip fabrication of artificial cells, microfluidics laser intracavity detection, electrospinning and pattern transfer, on-chip cell culture and manipulation.

Based on these tools, they have been able to study basic phenomena related to on-chip cell culture and cell network formation and evolution, as well as photocontrol of DNA conformation, and transcription activity.

Among other points they have developed a highly parallel nano-device for long DNA separation, novel methodologies for the preparation of giant liposomes of controlled size and composition, and their application as artificial cell models, and finally they are able to develop systems biology on a chip. For example, through the exploration of various flow conditions in microfluidic channels, their set-up allows studying the responses of E-coli under various stationary or dynamic conditions and exploring factors of variability in monoclonal populations of living cells.

With more than 100 papers in peer-reviewed journals, 27 invited conferences in 4 years, the team, already well recognised worldwide, has had a very significant scientific production, and of high quality, as expressed also by the number of citations.



The team aims at continuing exploration of the potentiality of microfluidic systems in life sciences and this can be supported, based on the proof they have made in a short period of time that they are capable of proposing new methods such as single cell manipulation, cell sorting, and high throughput parameter screening. This will hopefully lead to a better understanding of the (de)-differentiation mechanisms, as well as understanding the molecular and physical principles underlying gene regulation, dynamics, and variability in biochemical processes like gene expression. This may have practical applications in diagnosis (DNA long chains characterization) in phototherapy, cancer treatment, ...

The main problem with this team is its small size (one assistant professor position will help), still rather poor equipment (although having a clean room and a lot of cleverness to develop in-house systems) and, although having significant budget and cooperations, it does not have clearly the means for its ambitious long term development. Beyond the existing cooperations (that indeed seem easier with far abroad teams than in the short Parisian perimeter), Federating (in one way or another) the activities existing today at ENS, ESPCI, Curie, ... might be relevant in the course of a large project with critical masses on the Montagne Sainte-Geneviève? More connections with life sciences teams are also recommended.

In conclusion, a very good team, with significant results after a rather short period of time, that deserves more resources and integration in collaborative networks.

- **Strong points:** A very rapid development after 4 years of existence with significant scientific productivity and worldwide recognition by papers and conferences. A great cleverness in the production of in-house microfluidic systems. A very good complementarity in the team. A strong network of collaborations, mainly international (China, Japan, Italy, ...).
- **Weak points:** The group is still a small team. Rather poor equipment and laboratory facilities (apart from the clean room).
- **Recommendations:** Too much dispersion of the fluidics activity in the academic Paris teams. Federating (in one way or another) the activities presently existing at ENS, ESPCI, Curie, ... might be relevant in the course of a large project needing critical mass. More connections with life sciences teams are also recommended.

Nom de l'équipe : Microfluidics, Chemical organization, and Nanotechnology

Note de l'équipe	Qualité scientifique et production	Rayonnement et attractivité, intégration dans l'environnement	Stratégie, gouvernance et vie du laboratoire	Appréciation du projet
A	A+	A+	A	A

Team 5 : Ultrafast Photochemistry and Photobiology

Modern science is multidisciplinary in nature, and requires the involvement of new tools both for experimental and theoretical research. The sophistication of these tools demands an infrastructure in technical support and laboratory facility. Moreover the quality and number of personnel involved is critical.

A representative case is that of ultrafast photochemistry. To be at the cutting edge, the above stated requirements are essential for reaching the goal. The group in femtoscience will not be world class without the technical know-how from physics and engineering, the necessary equipment, and, of course, the leadership that stimulates and guides new frontiers of research.



The current activity in ultrafast photochemistry at ENS is respected worldwide and the work brings about collaboration also worldwide. The research is uniquely significant because of the interface between photochemistry and photobiology. If ENS wishes to continue in this field, it is important to recognize the needs to establish the laboratories on a par with other centres of similar repute in the world.

- **Strong Points:** Real focus on photophysical processes of photoactive molecular systems. Acknowledged publications in respected journals. International collaboration.
- **Weak Points:** Insufficient technical support and staff to bring the femtoscience to the new frontiers of research in the world.
- **Recommendations:** A new level of funding together with the appointment of the new generation of science leaders.

Nom de l'équipe : Ultrafast Photochemistry and Photobiology

Note de l'équipe	Qualité scientifique et production	Rayonnement et attractivité, intégration dans l'environnement	Stratégie, gouvernance et vie du laboratoire	Appréciation du projet
A	A+	A	A	A

5 • Recommendations and advice

– Strong points:

The unit produces work of very high quality of which much is internationally leading and pioneering (*vide supra*) reflecting a grouping of teams which is scientifically synergistic and well directed. This added value is already of high benefit.

– Weak points:

The unit whilst performing to a world class level appeared to be handicapped in three respects. First some areas appeared to be under-equipped by international standards. Second there was a clear need for increased technical support and for the assurance of sustained secretarial help at a level necessary for the unit's viability. Third the quality of the buildings occupied by the unit fell a long way short of what would be expected for a unit hosted in an institution with ambitions to remain world class.

– Recommendations :

We encourage the unit to consider further enhancing this successful grouping of teams by more formal collaborations both internally and also externally, as noted above but also, for example, in the development of institutional links certainly with Physics and perhaps Biology within ENS.

The remediation of technical support as well as the quality of the building and a part of equipment is essential to maintain and enhance yet further the work of this exceptional unit.



Note de l'unité	Qualité scientifique et production	Rayonnement et attractivité, intégration dans l'environnement	Stratégie, gouvernance et vie du laboratoire	Appréciation du projet
A+	A+	A+	A	A+



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Ref : YG/EF 2009.022bis

Paris, le 29 avril 2009

OBJET : Rapport d'évaluation du Laboratoire P.A.S.T.E.U.R- UMR 8640

Je vous prie de bien vouloir trouver ci-joint les observations du Directeur du Laboratoire P.A.S.T.E.U.R, UMR 8640, concernant le rapport d'évaluation de son unité.

Avec nos salutations les meilleures.



Yves GULDNER



ECOLE NORMALE SUPERIEURE

DEPARTEMENT DE CHIMIE

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Réponses et commentaires sur le rapport AERES sur l'UMR 8640

Tout d'abord, nous tenons à féliciter les membres du Comité pour l'excellent travail d'analyse et d'évaluation réalisé et pour la pertinence de leurs recommandations. Les commentaires suivants n'ont donc pour but que de préciser certains points techniques qui pourraient donner lieu à une interprétation erronée lorsque ce rapport sera utilisé dans le futur.

Evaluation du groupe de photochimie et photophysique ; paragraphe « recommandations » (Team 5 ; page 12) : Nous sommes entièrement d'accord avec l'analyse et les recommandations faites. Ce groupe bien qu'excellent n'a jamais réussi à atteindre une taille critique du fait des trop faibles fréquences de recrutements imposées par notre système. Il en est de même au niveau des équipements sophistiqués et coûteux que demande ce type de recherches pour se maintenir au niveau d'excellence souhaité.

Nous espérons que nos autorités de tutelle comprendront que les recommandations faites par le Comité concernent non pas la valeur des chercheurs du groupe mais les carences de notre système en matière de soutien financier et humain.

Paragraphe « recommandations » du point 5 : Nous remercions le Comité pour exprimer sa reconnaissance des travaux réalisés dans l'unité et sa détermination à l'aider à convaincre ses tutelles de lui donner les moyens humains et matériels de maintenir sa position de tout premier rang au niveau international.

Néanmoins, nous nous étonnons du commentaire recommandant à l'unité d'envisager des collaborations avec les Départements de Physique et de Biologie de l'ENS. En effet, des collaborations actives avec ces deux départements existent déjà en impliquant plus particulièrement les groupes 1, 3, 4 et 5 soit directement, soit via des contrats Européens impliquant certains de ces groupes et des groupes des départements de Physique ou de Biologie selon le cas. De même le système de salles blanches de l'ENS a été développé en accord et avec un soutien mutuel entre l'UMR 8640 du Département de Chimie et le Département de Physique. En outre, l'UMR 8640 a joué un rôle moteur dans la constitution du RTRA « Fondation Pierre-Gilles de Gennes », et y joue aujourd'hui un rôle actif en partenariat avec les acteurs majeurs en Chimie Analytique, Biologie et Biophysique de cette Fondation qui regroupe au-delà des départements de Physique et de Biologie de l'ENS, l'ESPCI et l'Institut Curie.

Fait à Paris le 29 Avril 2009



Christian Amatore
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Membre de l'Institut, Académie des Sciences