

transition-metal and organometallic chemistry, which also had a strong impact on the future projects of my group. Many researchers have been associated to the work of our team, “Laboratoire de Chimie Organo-Minérale”. In spite of the expected and unexpected difficulties they frequently had to face in the course of their work, these researchers have always been very enthusiastic and efficient. I owe them the success of our research team. The names of our CNRS researchers or University members (from assistant to full professors), of our PhD students and postdoctoral researchers as well as those of other visitors who contributed to our research are listed in Figures 19 and 20. Finally, I thank my parents, my wife Carmen, and my son Julien, for their continuous support and for their forgiveness regarding my pace of work and travel.

Laboratoire de Chimie Organo-Minérale

1. Members of the University of Strasbourg or of CNRS

Marc Beley, Christiane Dietrich-Buchecker[†], Jean-Claude Chambron, Jean-Paul Collin, Valérie Heitz, Jean-Marc Kern[†], Stéphanie Durot, Angélique Sour, Valérie Sartor

2. PhD students

Pascal Marnot, Romain Ruppert, Jean Weiss, Jean-Claude Chambron, André Edel, Abdelaziz Jouaiti, Sylvie Chardon-Noblat, Catherine Hemmert, Stéphane Guillerez, Christophe Coudret, Valérie Heitz, Abdelhakim Bailal, Angélique Sour, Jean-François Nierengarten, Fabrice Odobel, Sandrine Chodorowski, Aude Livoreil, Nathalie Solladié, Jean-Luc Weidmann, Gwénaél Rapenne, Myriam Linke, Laurence Raehm, Isabelle Dixon, Anne Chantal Laemmel-Gouget, Didier Pommeranc, Christine Hamann-Schaffner, Etienne Baranoff, Pierre Mobian, Benoit Colasson, Pirmin Roesel, Damien Jouvenot, Nicolas Belfrekh, Sylvestre Bonnet, Benoit Champin, Christian Tock, Julien Frey, Fabien Durola, Jacques Lux, Julie Voignier, Jean-François Ayme, Yann Trolez, Maryline Beyler, Cécile Roche

Figure 19. 1. Permanent researchers of the “Laboratoire de Chimie Organo-Minérale” (LCOM): University members and CNRS researchers including the late Dr. Christiane Dietrich-Buchecker (1942–2008) and late Prof. Jean-Marc Kern (1944–2004). 2. PhD students listed by chronological order. The two first students, Pascal Marnot and Romain Ruppert, started their PhD work in 1980.

Laboratoire de Chimie Organo-Minérale

Post-doctoral researchers and other visitors

David Amabilino, Audrey Auffrant, Christine Beemelmans, Martial Billon, Maria-Jesus Blanco-Pillado, James I. Bruce, Diego J. Cardenas, Ricardo Carina, John D. Crane, Christian S. Diercks, Vincent Duplan, Jonathan A. Faiz, Yoshio Furusho, Pablo Gaviña, Christine Goze, David Hanss, Neri Geum Hwang, Akiko Hori, Elisabetta Iengo, Fumiaki Ibukuro, Stuart James, Maria Consuelo Jimenez, Antoine Joosten, Robert Kayhanian, Jérôme Kieffer, Abdel Khemiss, Masatoshi Koizumi, Tomáš Kraus, Ulla Létinois-Halbes, Jacques Lux, Alexander G. Martynov, Dennis Mitchell, Bernhard Mohr, Cécile Moucheron, Frédéric Niess, Laure-Emmanuelle Perret-Aebi, Ingo Poleschak, Alexander I. Prikhod'ko, Felipe Reviriego, Zeinab Saad, Efsthathia G. Sakellariou, Xavier J. Salom-Roig, Emma Schofield, Hideki Sugihara, Pierre Louis Vidal, Michael D. Ward, Noémie Weber, Oliver Wenger, J. A. Gareth Williams

Figure 20. Postdoctoral researchers and other visitors.

Biography

I was born on October 21st, 1944 in Paris, just after the end of the second world war and a few months after Paris had been liberated by the allies and the French army led by General Charles de Gaulle (19–25 August 1944). My mother's name was Lydie Angèle Arcelin and her family came mostly from Normandy. She was born in 1920. My father was Camille André Sauvage and came from the Northern part of France. Camille Sauvage was known as a successful jazz musician, both conductor and clarinetist on top of being a composer. Just after the war, he was a popular jazz player and, later on, he composed for French radio, television, and movies. When I was a baby, my parents broke up. I stayed with my mother, while my father departed to pursue an artist's life. While I was still a young child, my mother met an officer in the air force, Marcel Louis Grosse, and they founded a family. I was, thus, fortunate to have a stepfather who took care of me until I became an adult and whose role was truly that of my father. Thus, I always considered him as my real father and I still do. Since my stepfather was in the military and because my parents loved to travel from one place to another, I had a very mobile childhood. When I was three years old, we moved to North Africa, as Algeria and Tunisia were still French colonies at that time. I still have vivid memories of our time in Zarzouna, a small village close to Bizerte in Tunisia. I also spent some time near Oran, in Algeria. I went to school in Tunisia between the ages of 5 and 7. At that time, the French kids and the local Tunisian kids were together in the same classes and I do not believe there were any difficulties related to the fact that the French kids and the Tunisian ones were mingling.

My mother and my grandmother, Suzanne Arcelin, were very close to one another, and my grandmother, who used to live in Paris, visited our family a few times. On a particular occasion, we went to southern Tunisia for sightseeing and the photo which is shown below is particularly representative. It was taken when I was about 4 years old.

From 1951 to 1952, my family spent some time in the USA since my stepfather had to become a military engineer in the field of radar applications, a relatively new technology at the beginning of the 1950s. We thus spent 6 months in Saint Louis,



Figure 21. In Tunisia with my mother and, on the left, my grandmother.

Missouri, followed by an additional period of 6 months in Denver, Colorado. I had no difficulty in adapting and in Denver, in particular, I used to play with the other children of our neighborhood. In Saint Louis, we used to go to the movie theater from time to time and it was, of course, a very enjoyable event for me. The picture shown below is interesting in the sense that one can see who were the most popular actors of the time.



Figure 22. After a movie in Saint Louis (USA) in 1951.

When we returned to France, we started a long period of itinerancy, spending a few months in a given place before moving to a new city. I thus went to 4 or 5 different schools in the west part of France and in the Paris area when I was 8 to 10 years old. My mother became ill when I was about 10 and it was a difficult moment for my family. She had contracted tuberculosis, which was a very serious disease in the 1950s. I was thus mostly with my grandmother for about a year, in the family village of Pacy-sur-Eure in Normandy. After this period, I was again with my parents, who moved to the eastern part of France in the Lorraine region. When I was 15 years old we moved to a small village in the north of Alsace, Drachenbronn, because my stepfather had been transferred to the radar station located on the Maginot Line named “Base Aérienne 901 Drachenbronn”. This move coincided with the beginning of my high school studies and I thus went to the high school of Haguenau, a middle-size city not far from air base 901. I started to be very interested in chemistry when I was 15 or 16 years old and, in particular, I liked to play with

natural molecules such as chlorophylls which I extracted from plants. I had a small and very primitive chemistry lab in the cellar where I was separating chlorophylls on paper or distilling various mixtures. At school, I was probably better in mathematics than in physics or chemistry, but the interest of pupils for various topics is obviously very dependent on the personality of the teacher.

After my “baccalauréat” (the French examination obtained at the age of 18 which enables to go to university), I decided to enter a special and highly competitive structure named “classes préparatoires”, which was aimed at preparing the young people to compete for admission in engineering schools. Thus, after two years of a rigorous regime where leisure was limited to a strict minimum, I succeeded and I was admitted to the Chemical Engineering School of Strasbourg. This was exactly what I wanted, since I could stay in my new, but already beloved, city. I obtained my engineer diploma in 1967 and I started my PhD thesis in 1967 under the guidance of Prof. Jean-Marie Lehn. Jean-Marie had founded his own research team a few years before I started to work with him. He was only 5 years older than I and his research team was developing rapidly in terms of size and breadth of his research interests. Being more a physical chemist up until 1967, he had become interested in making new molecules with novel properties when I started with him. At the time, Bernard Dietrich, formally a technician, decided to start his studies so as to become a graduate student, hoping also to do a PhD thesis. Bernard rapidly became my best friend and we worked together in the most friendly atmosphere imaginable between 1968 and 1971. Under the guidance of Jean-Marie, we were highly successful since we made the first macrobicyclic compounds able to encapsulate various ions, including alkali and alkaline earth metal cations (cryptands and cryptates for the metal-free compounds and their complexes, respectively). In Jean-Marie Lehn’s research group, I was able to acquire a solid background in organic and physical chemistry, thanks to my own work and to various seminars and group meetings as well as to the many hours I used to spend in the library. Discussions with Prof. Lehn and with other members of the group were also very fruitful. Equally important was the influence that Jean-Marie had on me in terms of the relationship between researchers within a group and, in particular, I enjoyed his way of managing a research team. He was very direct, placing basically no barrier between him and the PhD students or postdocs he was working with. In other words, hierarchy was reduced to its minimum and this is something which I tried to preserve later on in my own group. Inspired by Jean-Marie’s passion for science, I also became enthusiastic and determined to devote my life to research.

I met my wife Carmen in 1967 and we got married in February 1971. Carmen was a student in History of Art and Archaeology. She was particularly interested in ancient ceramics and had participated in several excavation campaigns on the Anatolian plateau, in Turkey. Although we were not especially religious, we had a religious wedding, mostly to respect family traditions. The wedding took place in Thierenbach, a village in the south of Alsace which used to be a place of pilgrimage and which is nowadays famous for its basilica.



Figure 23. The wedding ceremony in Thierenbach, February 8, 1971.

We were very happy to become parents of a baby boy, Julien Clément Sauvage, on July 13, 1975. It was a great joy for us. Since Julien's prime childhood, we have been very close to him. In 2011, Julien married Diana, originally from Columbia, and since 2012 they have settled down in San Francisco. They had a baby on April 9, 2016 so that Carmen and I became the happiest grandparents in the world.

At the end of my PhD thesis I obtained a CNRS position as "chargé de recherche" (research assistant) in Jean-Marie Lehn's group, which corresponded exactly to what I was so eager to get.

After my PhD thesis, I obtained a postdoctoral fellowship in Oxford (UK), where I spent a year in the research group of a very visible organometallic chemist, Dr. Malcolm L. H. Green. Malcolm was considered as one of the most brilliant former students of Prof. Geoffrey Wilkinson (1973 Nobel Laureate in chemistry with Prof. Ernst Otto Fischer). He was a very influential person in expanding my interests to transition-metal chemistry and organometallic chemistry. He was also a friendly person, who used to do experimental work by himself from time to time. Life in Oxford was particularly pleasant and we used to enjoy the city, its colleges, and its parks. We easily adopted the way of life of the other members of the Oxford community.

After my postdoctoral stay in Oxford, I came back to Strasbourg and, more precisely, to the Lehn laboratory as a permanent researcher. After some work in the field of chiral crown ethers, we initiated, Jean-Marie and I, a research project in a new field, at least in Strasbourg. It was related to photochemistry and solar energy. The first oil crisis took place in 1973 and it was a clear signal that alternative energies had to be found and that sustainable energies were crucially needed. Solar energy was an obvious and especially attractive option. A particularly appealing project was that of splitting the water molecule to H_2 and $\frac{1}{2}\text{O}_2$ in order to generate a nonpolluting fuel, H_2 , using photonic energy. Such a big project had already been explored for many years by several groups and there were already discussions and research works published on this general topic in the 1950s and later on. More or less at the same time, the ruthenium complex $\text{Ru}(\text{bipy})_3^{2+}$ ($\text{bipy} = 2,2'$ -bipyridine) was shown to display promising electronic properties in its ground or excited states, in particular in relation to electron transfer and potential photochemical water splitting. In 1977 we published one of the very first systems leading to photochemical water reduction to H_2 based on a combination of species such as, in particular, $\text{Ru}(\text{bipy})_3^{2+}$ as a photoactive species and $\text{Rh}(\text{bipy})_3^{3+}$ as an electron relay leading to H_2 formation. After two years of studies on this original system (with Jean-Marie Lehn and Michele Kirch) and related ones, as well as on the development of a light-driven oxygen-generating system from water (with Jean-Marie Lehn and Raymond Ziessel), I was lucky enough to be promoted to the position of CNRS Research Director, the equivalent of University Professor. I thus founded my own research group in 1980, at first with two highly motivated PhD students, Pascal Marnot and Romain Ruppert. After one or two years, Jean-Paul Collin, a CNRS fellow, and Marc Beley, an Associate Professor, joined our small team. Simultaneously, a good friend of mine, Christiane Dietrich-Buchecker, also joined. As it is often the case for young research teams, we tackled several research projects in parallel in relatively remote areas. The electrochemical reduction of CO_2 using $[\text{Ni-cyclam}]^{2+}$ as electrocatalyst led to remarkable data, since CO_2 could be reduced very selectively to CO in water. This was somewhat surprising, since H_2 was expected to be obtained as a major reduction product. We also did work in homogeneous catalysis and inorganic photochemistry. In this latter field, our projects were mostly triggered by a collaboration with David R. M. McMillin who was on sabbatical leave in Strasbourg. David was an already well-established photochemist and photophysicist. He was a professor at the university of Purdue (West Lafayette, USA) and his main field of research was copper(I) complexes photochemistry. This collaboration between our group, with its skill in organic synthesis, and David led to a series of particularly interesting photoactive copper complexes. Perhaps even more important, it led to a copper(I) complex containing two intertwined organic ligands which appeared to be the ideal precursors to a compound comprising two interlocking rings. It was thus very tempting to jump from inorganic photochemistry to interlocking ring compounds which, at the beginning of the 1980s, seemed to be practically inaccessible molecules. This

jump was made possible due to the expertise of Christiane Dietrich-Buchecker, who was a great organic chemist. After a few discussions within our team, we decided to take the risk and to embark on a totally new project concerned with the synthesis of catenanes (i.e. interlocking ring compounds). Within a few months, Christiane was able to develop an efficient preparative procedure for making our first [2]catenane (containing 2 interlocking rings). Respectable quantities could be obtained: batches of 0.5 g could be prepared, in particular by Jean Weiss, a PhD student also supervised by Christiane, and the first compound was fully characterized using a variety of techniques. ^1H NMR provided the first convincing evidence that a [2]catenane was indeed produced. These experiments were carried out by Jean-Pierre Kintzinger, a friend of mine and the brother-in-law of Christiane, who was at the same time an NMR expert. We published our first paper in this field in 1983 in an acceptable, but not high-impact, journal (*Tetrahedron Letters*). It was for us the beginning of a new era, mostly but not exclusively devoted to interlocking rings compounds and knotted molecules. The field has often been referred to as “Chemical Topology” due to the fact that the compounds have nonplanar molecular graphs. In other words, contrary to almost all the molecules known, it is impossible to draw them in a plane (i.e. on a sheet of paper) without crossings, regardless of the deformation the molecule can be subjected to.

Besides chemical topology and molecular machines, our group has been active in various relatively remote fields. The principal alternative research area has been that of artificial photosynthesis, with a particular emphasis on photoinduced charge separation, one of the key processes of natural or artificial photosynthesis. In order to elaborate efficient models of the natural photosynthetic systems, and in view of realizing the complete water splitting cycle in the future, our group synthesized numerous multicomponent complexes, either incorporating metal-complexed porphyrins or second- or third-row transition-metal complexes (Ru, Os, Rh, and Ir) able to undergo light-induced charge separation. Following the synthetic work, the photochemical and photophysical properties of most of the compounds were investigated in various places by more physical chemistry oriented research teams than ours. In particular, a long-term collaboration with renowned photochemists located in Bologna turned out to be specially pleasant and fruitful (Balzani and his co-workers, University of Bologna, or Flamigni and Barigelli, Consiglio Nazionale delle Ricerche, Bologna). Some of the charge-separated states were shown to be remarkably long-lived, thus paving the way to real artificial photosynthetic devices reminiscent of the photosynthetic apparatus of green plants or photosynthetic bacteria.

I would like to stress that encounters with various people played a very important role in my professional life. Two teachers were particularly influential when I was a student: Raymond Weiss, who was a very rigorous physical and inorganic chemist, and Guy Ourisson, an exceptional organic chemist who was able to convince all the students he was teaching to that organic chemistry is exciting and can even be fun. Jean-Marie Lehn had also a great impact on my enthusiasm for science, and to me he was the perfect model,

although this model was totally out of reach. One of the most important encounters was that with Christiane Dietrich-Buchecker, a wonderful person and a great organic chemist, whose contribution to the scientific production of our group turned out to be determinant. Finally, it may appear as surprising that with Fraser Stoddart, we never looked at each other as competitors. Even more, we both tried to avoid any overlapping with the activities of the other research team. This is mostly due to the fact that we became friends at the end of the 1970s and this was the beginning of a faithful friendship which allowed us to work in a more serene atmosphere than if we had tried to overtake the other. Between 2010 and 2013, I was appointed as visiting professor at Northwestern University, where I collaborated primarily with Fraser and his team. I also enjoyed interacting with other



Figure 24. One of the ceremonies held in Strasbourg (1988) to honor Jean-Marie Lehn's Nobel Prize (1987). On this special occasion, the chemistry community gathered in a friendly atmosphere (as testified by the number of smiley people in the picture). From left to right, the four persons at the front are Jean-Marie Lehn, Jean-François Biellman, myself, and Guy Ourisson. My very good friend Bernard Dietrich (1940–2004), who was also one of the main contributors to the early work on cryptands and cryptates, is in the second row just behind J.-F. Biellman.



Figure 25. Picture taken on the stage, after the Nobel Ceremony with the Royal Family. From left to right : Annelie Almkvist, our Attachée, Diana Sistiva, our daughter in law, Julien Sauvage, our son, Carmen Sauvage, my wife, myself, and Jean-Marie Lehn.

colleagues in this great university. I am particularly grateful to Fraser for arranging for me to get such a position.

I would like to conclude with two pictures separated by approximately 29 years. The first one, Figure 24, was taken at the ceremony to honor Jean-Marie Lehn's Nobel Prize in 1987. This ceremony took place in the Great Lecture Hall of the Chemistry Department of our university. The second picture, Figure 25 is much more recent, since it was taken in Stockholm just after the 2016, December 10 ceremony.

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