Testimonial to Renato Ugo

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Professor Renato Ugo, Emeritus Professor of General and Inorganic Chemistry at the University of Milan, passed away on October 20, 2020. He was the quintessential renaissance man, having made outstanding contributions to education and research in academia, as well as to research, innovation, and management in industry, and to government policy impacting national and global society. He was uniquely gifted with the ability to move effortlessly between the three distinct sectors of industry, academia, and government. What characterized all of Renato's endeavours was his deep humanity, sense of humour, and love of life.

Renato was passionate about education as a lecturer, as well as being engaged in curriculum development. He was involved in the establishment of a Degree Course in Industrial Chemistry. Furthermore, in the mid-1990s, he played a significant role in the creation of a new degree program in Biotechnology. This initiative, together with the Biotechnology program at the University of Bologna, constituted the inaugural degree programs in biotechnology in Italy.

He was an exceptional educator, explaining new concepts and principles to students, by challenging and encouraging them to come forward with imaginative and innovative solutions, addressing questions of fundamental significance. By doing so, Renato inspired them to "think outside the box". Over a period of many years, his students and postdoctoral fellows often expressed to us their heartfelt admiration to Renato for everything he did to nurture their pursuit of success in achieving their aspirational goals. His devotion and commitment to his students and co-workers was awesome and enduring. He was so proud of them, and they are a living legacy of Renato's impact as a leader in education.

Renato was a trailblazer in fundamental and applied research. Excellence was his signature, whether in homogeneous or heterogeneous catalysis, or in relations between the two methodologies. He and Jean-Marie Basset were pioneers in surface organometallic chemistry. He made landmark discoveries in chemisorption. Practical applications of his research influenced the non-linear optics and the solar energy industry sectors.

Thus, Renato had the intuition that, whether heterogeneous or homogeneous, catalysis is a process controlled by a molecular phenomenon since it implies the transformation of molecules into other molecules. It follows that on the surface of metals or metal oxides involved as heterogeneous catalysts, the relevant surface species and the mechanism of their reactions should have a molecular character, as in homogeneous catalysis. He was a pioneer in this field. His first works date back to 1967-1968. The Plenary Lecture given on this subject in 1972 at the IV International Catalysis Congress (heterogeneous), in Palm Beach USA, is highly significant. An important review article was published in *Catalysis Review* in 1975 (*Catalysis Reviews*, 1975, 11, 225), where the molecular metal cluster concept as a model of a surface or of a metal particle was discussed for the first time. Renato contributed in outlining the molecular approach to the interpretation of catalysis by metals and in general of surface processes of heterogeneous catalysis.

This subject led to the new field of "surface organometallic chemistry" that Renato developed greatly, showing how the surface of a metal oxide behaves as a ligand of a surface organometallic molecular species. For example (*Inorganic Chemistry*, 1979, 18, 3104), he observed, with Jean-Marie Basset, how $[Rh_6(CO)_{16}]$ reacts with hydroxyl groups of the alumina surface to give Rh(I) species such as $[(Al\text{-}O\text{-})(Al\text{-}OH)Rh(CO)_2]$ bonded to the oxygen atoms of the inorganic oxide with formation of molecular hydrogen. The molecular metal carbonyl cluster could form in the presence of water and CO. These results showed that a rich and fascinating surface chemistry could occur when adsorbing molecular metal carbonyl clusters on the surface of an inorganic oxide. Similarly, it was found that $[M_3(CO)_{12}]$ (M = Ru, Os] reacts with silanol groups of the silica surface affording a surface molecular species, $[HM_3(CO)_{10}(OSi\leqslant)]$, which could be disaggregated thermally to produce silica-anchored carbonyl M(II) species that recombine in the presence of water and CO to regenerate the original cluster. A novel research field was emerging leading to many reports.

The understanding that surface metal carbonyl fragments can be highly mobile was the springboard for considering the surface of an inorganic oxide as a reaction medium for organometallic reactions. In particular, Renato discovered at the beginning of 1990s that the silica surface can be an extremely efficient medium for synthesis in high yields, high selectivity and under mild conditions of a series of metal carbonyl compounds starting from the related metal salts. By addition to the silica surface of an alkali carbonate, metal cluster anions can by synthetized as well, without the need of superbases. This new methodology of synthesis allows the preparation in large quantities of metal carbonyl clusters of high nuclearity previously prepared by difficult and low yield synthetic routes. In parallel, in order to get a deep understanding of surface organometallic chemistry, Renato developed the theme of the

synthesis and reactivity of complexes with silanolate ligands as models of molecular species supported on silica.

In the early part of the 1990s, Renato was attracted by an emerging area of research on materials for photonic and electro-optic applications. In this period, the impact of organometallic and coordination chemistry and the understanding of the role of the nature of metal centers on the nonlinear optical (NLO) properties of molecular and crystalline materials for photonic and optoelectronic were still limited. Renato first focused his attention on the role of the metal center and of its coordination sphere on the second-order NLO properties of metal coordinated pyridines and stilbazoles substituted in the *para* position with an electron-donor or acceptor group. He found that the quadratic hyperpolarizability of these ligands, measured in solution by the Electric-Field Induced Second Harmonic generation (EFISH) technique, increases upon coordination to various metal centers, such as Ir(I), Rh(I), and Os(II), the enhancement factor being modulated by the nature of the metal (electronic configuration, oxidation state, coordination sphere) which can act as an electron-acceptor or an electron-donor depending on the substituent of the ligand. When the substituent is a strong electron-donor group, the increase of the value of the quadratic hyperpolarizability is dominated by an intraligand charge transfer transition, with the metal center behaving as an electron-acceptor, whereas when the substituent is an electron-acceptor group, the increase of the value of the quadratic hyperpolarizability is dominated by a metal-to-ligand charge transfer transition, with the same metal center behaving as an electron-donor. The related first paper of Renato in the emerging field of coordination compounds for second-order nonlinear optics (*Organometallics*, 2000, 19, 1775) has been in the last twenty years a spring of inspiration for researchers in Italy and in the world, and led to the design of various coordination compounds and porphyrinic systems with a high second-order NLO response, in some cases switchable for example by introduction of a photochrome moiety. Renato collaborated with world experts in the area of electrooptics and photonics, thinking that the spirit of collaboration is the strength of scientists, which make them unique people. In the Department of chemistry of the University of Milan, he built up a laboratory for NLO measurements in solution (EFISH technique), on powders (Kurtz-Perry technique) and on films (Maker-Fringes technique). This laboratory is unique in Italy and one of the few in the world.

The breadth of knowledge of science, management, and policy by Renato served him well in influencing industry in Italy and beyond. In the Montedison Group of Companies, whether as advisor, or as responsible for all research and development, he relentlessly pursued new avenues for the company to consider, resulting in opportunities to position Montedison advantageously in competing on the world stage. This *was* the golden age of research and innovation at Montedison. In 1983-86, he was also the President of the prestigious Guido

Donegani Research Institute in Novara, which was then part of the Montedison Group. He served on the Board of Directors/Governors of a substantial number of corporations, in different industry sectors such as pharmaceuticals, materials, fine and specialty chemicals, and optics. Specific examples in addition to the Montedison family of firms was Renato being a member of the Board of Farmitalia-Carlo Erba in the pharma sector, and of Isagro in agricultural and other products. In February, 2021, at a ceremony in Novara, Giorgio Basile, President of Isagro hosted a ceremony announcing that its research center would henceforth be known as the Research and Development Center Renato Ugo, in honour of Renato.

During the period 1983-2019, Renato was President of the Associazione Italiana per la Ricerca Industriale (AIRI). This Italian Industrial Research Association included about 40-50% of Italian companies that worked together as a consortium for economic and societal advancement in Italy.

Renato spent much time and energy counselling the Government of Italy on research, universities, and industry, especially but not only, on policy issues. For instance, he served in different capacities in the Italian National Research Council (CNR), including as a member of the Board of Directors during 2004-2008. He was a sought after advisor –informal, as well as formal—to a number of Ministers of Research and Universities in different Italian Governments. He was Chair or a Member of Committees in the Ministry including the Committee for the Evaluation of Research in Italy during 2003-2006.

During his career Renato Ugo published more than 340 papers and 15 patents. He gave numerous invited, plenary, and keynote lectures at different universities, companies, and in government laboratories, as well as at national and international conferences/symposia/workshops around the world. Examples included the British Council Lecture Tour (1973) and the François Gault Lecture (1982). In 1997, he was the British Petroleum (BP) Lecturer at the University of Ottawa. His presentations were enthusiastically received by the audience. In addition, he had stimulating discussions with students, postdoctoral fellows, and faculty during his stay at Ottawa as the named BP Lecturer.

Renato received major awards and prizes for his groundbreaking achievements during his career. In 1988, he was the recipient of an Honourary Degree from Clarkson University in Potsdam, New York (U.S.). Two years later, he was elected as a National Member of the Accademia Nazionale dei Lincei. Last year on March 20, 2020, he was awarded the Gold Medal, the highest recognition given by the Accademia Nazionale Delle Scienze Detta dei XL [National Science Academy of Italy]. In 2000, the President of the Republic of Italy conferred the Republic's Gold Medal for Merit for Culture and Science to Renato Ugo. In Firenze, in 2006,

the Italian Chemical Society's Industrial Chemistry Section awarded Renato Ugo the Piero Pino medal, for his phenomenal contributions to industrial chemistry.

Personal Memories (Howard):

Renato Ugo was a very special person. He was not only a dear friend, but also was a mentor to me. I learned so much from him. His generosity of spirit was second to none! Whenever we arranged to meet and discuss different subjects in a frank and completely open fashion, I came away exhilarated by these precious times together. He was an intellectual giant. We enjoyed memorable meals together, sometimes just the two of us, and at other times with our spouses or others. We also benefitted from other types of activities working together, one example being the Accademia Nazionale dei Lincei-Royal Society of Canada joint workshop held at the Accademia Nazionale dei Lincei in 2004. Renato and I were the Co-Chairs for this Workshop. I will always remember that, in 2001, Renato organized a "Symposium in Honour of the Sixtieth Birthday of Professor Howard Alper" in Milan, Italy. I was humbled and indeed totally surprised by this extraordinary act of kindness by Renato, a truly selfless individual.

Renato Ugo and Maddelena Pizzotti were married on May 26th 1973. What always impressed my wife (Anne) and I was the warmth and affection of their relationship. In his life, Renato had to confront monumental health challenges which required major medical procedures including two heart transplants. Renato faced these issues with confidence, and with his usual irrepressible optimism. And Maddelena, the love of his life, was a remarkable caregiver to Renato—his "Rock of Gibralter".

Personal Memories (Dominique):

After my PhD, in April 1989, I joined the laboratory of Renato, following the advice of my supervisor Howard Alper. I was immediately struck by his exceptional chemical intuition, his extraordinairy and varied culture, his deep humanity, his kindness.

A few months after my arrival, Prof Ugo's health deteriorated. Before Christmas I went to visit him at home to talk about chemistry (despite his weakness he was deeply interested in everything that went on in his laboratory) and he said to me "you know, *sono alla frutta*, do you know what that means? After that there is only coffee" (this means "I'm almost at the end", because in an Italian meal, after fruit there is coffee only). I remember the sadness that invaded me. But deep down in my heart I knew it couldn't go wrong, that he would recover and I told him. Then he had his first hearth transplant on December 27, 1989. He recovered quickly, as he also did for the second heart transplant, reading, writing and correcting articles

in the hospital. He always has been a lion, as he used to say, endowed with an overwhelming energy.

In more than 30 years of strong collaboration, he has been an exceptional guide. Despite his commitments, he always found time to discuss the chemistry going on in his laboratory, always ready to give innovative ideas and advice and solve scientific or personal problems. He loved chemistry. He used to say that chemistry is both a logical and a creative fact; once you understand the logic behind it, the rest is creation, like that of a tailor or painter. For Christmas he always brought his research group to a pizzeria.

I used to do oral exams with Renato for the course in inorganic chemistry. He had unique skills as professor. He made the students think, he wanted them to understand and succeeded. He was loved by his undergraduates and doctoral students. Many of them have become professors, entrepreneurs, responsible for public and industrial research, maintaining friendly ties with him who was always ready to help and give wise advice.

The treasurable discussions and moments I had with Renato are unforgettable.

In conclusion, those who had the privilege to know Renato Ugo, will remember him as a great leader, superb research scientist, brilliant educator, and administrator. He was always encouraging others to achieve beyond what they thought was possible. He engaged with people in all walks of life. His humanity was unforgettable. He was not only a treasure for Italy. He was a world treasure.

May the memory of Renato Ugo forever be a blessing.