INTERNATIONAL MICROBIOLOGY (2005) 8:63-68
www.im.microbios.org

INTERNATIONAL MICROBIOLOGY

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Joan Oró (1923-2004)

Joan (John, in English) Oró Florensa was born in Lleida, Catalonia, Spain, on October 26, 1923, the youngest of five children and the only male. Due to the Spanish Civil War (1936-1939), his graduation from high school was delayed until 1941. He then studied at the University of Barcelona, where he obtained his degree in Chemistry in 1947. Already as a child, young Oró was interested in the chemistry of life. Since at the time he entered university there were no studies in biochemistry in Spain, he decided to pursue a degree in chemistry and to focus on organic chemistry. After his graduation, he returned to his hometown, Lleida. There he tried first, unsuccessfully, to earn his living as a chemist; afterwards, he spent 3 years working at his father's bakery, saving money in case he had the opportunity to return to chemistry. Nevertheless, he had mixed feelings about what to do. Whereas he longed to start a career in biochemistry, and thought that he and his wife (Francesca Forteza, to whom he married in 1948) could make do with a small salary, they already had three children: Maria Elena, Joan and Jaume (the youngest son, David, was born when the family was already living in Houston). He knew that if he kept working in the bakery, he and his family would not have financial problems in the future. However, making such a decision would mean not working at what he enjoyed the most and in the field for which he had been trained.

Fig. 1. Joan Oró (1923-2004).

He decided to take another risk and go to the United States. In 1951, through the Institute for North-American Studies in Barcelona, Oró made a list of more than fifty universities in the United States and sent letters to all of them requesting information. Four of the universities that answered his request offered him free tuition. He chose to enroll at the Rice Institute in Houston, Texas. Oró arrived in Houston on August 2, 1952, to start his graduate studies in chemical engineering. A few months later, he met Donald Rappoport, who was Professor of Biochemistry at Baylor College of Medicine, and needed a graduate student to help him in his research on metabolism. The study in which Oró participated was aimed at elucidating some of the features of rapidly dividing, healthy cells in order to better understand the biology of cancer cells.

Oró studied the incorporation of carbon-labeled formate into animal tissues and the fate of this compound. He discovered that a major portion of the formate metabolized by sections of jejunum was incorporated into serine, cystathionine, and other acid-soluble products, and another portion was oxidized to CO_2 by a catalase–hydrogen peroxide complex. Based on that work, Oró demonstrated that molecules essential for life can be synthesized from other very simple ones, as was the case of formate, which has only one carbon. By mid-1955, Oró had finished the experimental part of his doctoral thesis and thought that he would be ready to defend it in a few months. The Dean of Baylor School of Medicine recommended, however, that he waited until 1956; otherwise people might have the impression that doctorates could be obtained quickly at that school. While completing his thesis, Oró taught as an instructor in the

Department of Chemistry of the University of Houston. He had to work very hard to cope with the five subjects he had to teach in addition to writing his doctoral thesis, which was not easy since he was not yet fluent in English.

At the Department of Chemistry of the University of Houston, Oró worked successively as Assistant Professor (1956-1958) and Associate Professor (1958-1963) before being appointed Full Professor, in 1963. By then he had already achieved one of his major goals in research: synthesizing adenine under laboratory conditions. Having obtained amino acids from hydrogen cyanide, water, and ammonia (the results of this experiment were not published until 1960), he then focused on the synthesis of adenine from glycine and several simple compounds. A student of his started the experimental work, which soon seemed to demonstrate the production of large amounts of adenine. Oró thought that such yields must be almost impossible to obtain and checked the results, only to realize that the graph that the student had interpreted as adenine in fact corresponded to the solvent that had been used. Remembering his earlier results, Oró considered the possibility of synthesizing adenine from ammonium cyanide. In fact, chromatography had shown a small spot corresponding to adenine. Perhaps he would be able to increase the adenine yield by using more nitrogen cyanide. On Christmas Eve, 1959, he concentrated a mixture of the starting ingredients and then allowed the solution to stand overnight. The following morning, when he returned to the lab, chromatographic analysis revealed a large black spot, which under ultraviolet light was confirmed to be adenine. He had done it! This experiment opened a new field of research that eventually led to the laboratory synthesis of the rest of the components of nucleic acids.

The most amazing conclusion Oró drew from that result was that a molecule essential for life, such as adenine, could be synthesized from ammonium cyanide, which is a lethal compound for respiration. Melvin Calvin (Chemistry Nobel Prize winner for his work on the mechanisms of photosynthesis in 1961) was among the first to recognize the significance of Oro's experiment and invited him to join his team at the Lawrence Radiation Laboratory of the University of California-Berkeley in the summer of 1962. Oró did not accept, choosing instead to stay in Houston.

In 1961, Oró suggested that cometary collisions with the Earth might have contributed to increasing the amount of carbon compounds in the early planet, thus promoting the prebiotic synthesis of biochemical molecules. He also suggested that comets had brought water to Earth. In fact, even if the young planet Earth was assumed to have had water, it probably escaped to outer space along with some mass of the planet as a result of a collision with a body the size of Mars. Later calculations showed that the amount of carbonaceous matter that reached the Earth as a result of cometary collisions might have been as large as 10^{12} grams.

In 1963, Freeman Quimby, who chaired the Life Sciences Department at NASA, invited Oró to join the group that would work on organic chemistry studies of the Apollo project. He was the Principal Researcher of the Houston University team that collaborated in the project and which had developed equipment for chemically analyzing lunar samples, both in situ—on the Moon—and in the laboratory—once the samples had been taken back to the Earth. The two scientists developed a small portable mass spectrometer that could analyze low-molecular-weight molecules. Even though that device was not used on the Moon, it was the basis for the mass spectrometer used in another NASA mission, the Viking project to Mars. Participation in the Apollo project made it possible for Oró's laboratory at the University of Houston to obtain state-of-the-art equipment for carrying out molecular analyses, for example, an apparatus combining mass spectrometry and gas chromatography that was crucial for meticulous analyses of complex mixtures. The study of lunar samples confirmed what many scientists had already suspected for years: there was no life on the Moon.

On July 20, 1976, the first Mars lander reached the surface of the red planet. Of the more than a dozen experiments carried out on Mars with the help of a robot, three dealt with biology. The most important consisted of mixing a sample of Martian soil with a solution that contained nutrients labeled with ^{14}C, including glucose and several simple amino acids such as glycine. Biologists were amazed to learn that the mixture produced a large quantity of ^{14}C-labeled carbon dioxide. Oró, however, had felt from the very beginning that life would not be discovered on the Mars surface because of the high degree of oxidation, and was skeptical of the interpretation of the results. When he discovered that formic acid was among the components of the test solution, he had an explanation for the result. He was familiar with the mechanisms of oxidation of formic acid, which he had studied as part of his doctorate. Formic acid oxidation is a common chemical, non-biological reaction.

Oró participated in the NASA Program of Organic Cosmochemistry until his retirement in 1994, studying organic synthesis under early Earth conditions and analyzing samples of meteorites, ancient rocks, and fossils. Before his retirement, and even afterwards, Oró was committed to the world of research both in the United States and in Catalonia. He chaired the first meeting of the International Society for the Study of the Origin of Life (ISSOL), which was held in Barcelona in 1973, and as the President of ISSOL was also one of the organizers of the seventh edition of the same meeting, which also took place in Barcelona, in 1993, under the direction of the author of this article. He participated in founding the Association of Friends of Gaspar de Portolà (which promotes academic and cultural ties between California and Catalonia, mainly through a scholarship program), as well as the Catalan Foundation for Research, whose mission is to further scientific research in Catalonia. In Lleida, his hometown, he set up his own foundation (Fundació Joan Oró), whose aim is to promote basic and applied research as well as ties between companies and universities and research centers.

In 1994, Oró retired from his academic and research duties at the University of Houston and returned to Catalonia. His wife Francesca (Paquita) had died in 1990, and in 1995 he married to Antonieta Vilajoliu, from Balaguer, Lleida, who was also a widow of a late friend of Oró.

Oró's final project was an ambitious one. He had always longed for Catalonia to have a first-class Center of Astrophysics in the Montsec (between Barcelona and Lleida), where the sky is clear and there is scarcely any light contamination. An astronomic and meteorologic study carried out by researchers of the University of Barcelona confirmed that, in fact, the village of Sant Esteve de la Farga, in the Montsec, was among the best locations in Catalonia to build an observatory. The project, currently under way, like Oro's other endeavors and accomplishments has a three-fold aim: research, education, and the dissemination of science.

The prestige of Oró transcended the scientific community in Catalonia and Spain, as evidenced by the recognition he received from universities, political institutions, and the general public. In Spain, Oró was granted honorary degrees from the Universities of Granada (1972) and Lleida (1999); was an honorary member of several scientific societies; and received many awards, including the Gold Medal of the city of Lleida (1976), the Narcís Monturiol Medal for Scientific and Technological Merit (1982), the Grand Cross of the Order of Aeronautical Merit (1983), the President Francesc Macià Labor Medal (2000), the Gold Medal for Scientific Merit of the City Council of Barcelona (2002), and the Gold Medal of the Generalitat de Catalunya (2004). On 23 June 2003 the King of Spain awarded him with the title of Marquise of Oró for his continuous dedication to the scientific world through his many research works, which "have contributed, in a remarkable way, to improve the knowledge of the origin of life." For his arms, Oró chose the adenine formula, surely the first molecule represented on a coat of arms in the history of heraldry.

It is always difficult to summarize the work and accomplishments of an extraordinary scientist; and Professor Joan Oró was one of those rare persons. But we can try to do so by listing some of the major discoveries from the 30 years of research carried out under his direction.

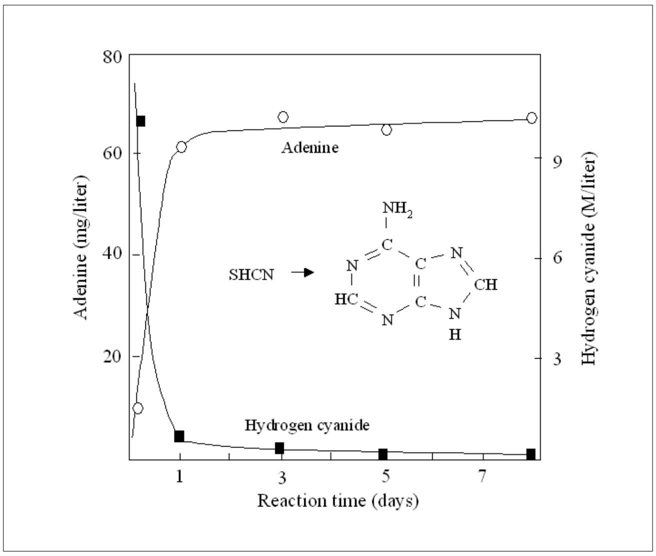

Fig. 2. The seminal experiment in which Oró showed the rate of adenine synthesis from ammonium cyanide at 90ºC.

The first prebiotic synthesis of adenine from hydrogen cyanide was accomplished during the period 1959-1962 (Fig. 2). Adenine is probably the most important biological molecule because of its key role as an essential component of DNA, ATP, and other biological molecules responsible for the genetic code, replication, enzymatic catalysis, and metabolism in all living systems. This work opened up an area of research that led to the complete synthesis of all components of nucleic acids. In 1961, Oró suggested that cometary collisions with the primitive Earth had contributed substantial amounts of carbon-containing compounds for the prebiotic synthesis of biochemical molecules. Later computations (1980-1982) showed that the amount of carbonaceous matter acquired by the primitive Earth from comets was probably of the order of 10^{23} grams. This is 100,000 times larger than the total mass of the present biosphere and accounts for the disappearance of the bulk of the Earth's primary atmosphere as a result of a collision with a Mars-sized body, which led to the evaporation of all the volatiles and the formation of the Moon (Earth–Moon system).

Beginning in 1958, Oró developed and applied new chromatography-mass spectrometry methods to the analysis of organic compounds synthesized under plausible primitive Earth conditions or present in extraterrestrial samples, such as meteorites and lunar samples. He was the first to analyze volatile amino-acid derivatives by applying these methods. In 1970, using optically active phases, he was also the first to detect D- and L-amino enantiomers in carbonaceous chondrites. This led to work by Kvenvolden and collaborators suggesting that organic compounds were chemically synthesized on meteorite parent bodies more that 4.5×10^9 years ago, when the solar system was formed.

From 1964 to 1977, Oró designed, developed, and tested an instrument for analyzing the atmosphere and surface volatile components of the planet Mars. He suggested the building of a new miniaturized gas chromatograph-mass spectrometer for the Viking mission to Mars. Four instruments of this type were built and integrated into four Viking Mars landers. Two of these spacecrafts were sent to Mars in 1976, and provided the first analysis of the atmosphere and surface of another planet. A complete analysis of the atmosphere and volatile surface components was eventually obtained but no organic compounds were found on Mars.

In 1976, Oró offered a chemical interpretation of the puzzling results obtained by other scientists concerning the presence of life on Mars. Based on his previous work from 1956, Oró was able to explain that the sudden and intense production of $^{14}CO_2$ by the Martian soil samples in the Viking test chamber was not due to the rapid metabolism of presumed Martian microorganisms, but rather to the catalytic chemical oxidation of the test nutrients, especially formic acid, labeled with ^{14}C by iron and other active oxides present in the Martian samples. The absence of evidence for life on Mars stopped the development of plans by NASA for subsequent manned exploration of the red planet.

During 1978-1980, Oró demonstrated the photocatalytic oxidation of organic compounds under simulated Martian conditions. The results showed that any organic matter present on the surface of the red planet that had been exposed to ultraviolet radiation from the Sun would have a very short lifetime, being oxidized to CO_2 and H_2O. This provided an explanation for the surprising absence of organic compounds on the Martian surface and additional evidence in support of the absence of life on Mars.

In 1963, Oró was the first to suggest that the synthesis of biological macromolecules, such as polypeptides and polynucleotides, could be carried out by means of condensing agents, such as cyanamide and imidazole derivatives. Indeed, this was demonstrated in many subsequent experiments that were carried out in Oró's laboratory at the University of Houston. Cyanamide is present in the interstellar medium, where it is an important organic molecule. During the years 1982-1984, many imidazole derivatives were synthesized in Oró's laboratory under possible primitive Earth conditions.

From 1978 to 1984, Oró's laboratory was able to synthesize most of the phospholipid components of cellular membranes, including phosphatidylcholine and phosphatidylethanolamine. Using such amphiphilic molecules, it was possible to obtain liposome vesicles similar to the membranes of most living cells, thereby demonstrating for the first time how the membranes of living organisms might have formed.

In the 1980s, Oró's laboratory carried out the prebiotic synthesis of histidine, histidyl-histidine, and a number of phosphorylated coenzymes and other enzymatically active compounds. Protocellular models involving liposomes and catalytically active RNA molecules were developed theoretically. Current experiments are testing the validity of these models.

Oró finally returned to Spain in 1994, after his retirement from the University of Houston. During the following 10 years he devoted his energies and attention to science and culture in his home country, Catalonia. Joan Oró died in the city of Barcelona on September 2, 2004, mourned by his second wife and four children. However, his work continues to motivate and inspire. Today, even though the riddle of the origin of life is still far from being solved, it has lost most of its shroud of mystery and is beginning to be understood in molecular terms—thanks to the intelligence and effort of outstanding scientists such as Professor Joan Oró.

Acknowledgements. I acknowledge Mercè Piqueras for her help in the editing of Prof. Oró's bibliography, which we received from Prof. Oró himself in 2003.

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The complete list of articles, chapters of books, books and doctoral theses directed by Prof. Joan Oró can be found in the online version of this article.
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