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The extraordinary life of Michel Boudart : A very personal perspective

Michel passed away eight years ago, at 87 years of age. Yet he continues to be very present to many of us, as demonstrated by this wonderful issue of *Journal of Catalysis* honoring his legacy. To this day, I carry with me an overriding impression about Michel: Every moment of his life, he embodied the totality of his scientific intensity and his academic lineage, both of which helped define his scientific values, his approach to his work, and the core beliefs he transmitted to his students. His commitment was reflected in his questions, his comments, his teaching and his mentorship. It was in his DNA.

I knew Michel from the day he arrived at Stanford University in 1964 and I was in my second year as an undergraduate student in Chemical Engineering. In the 50 years that followed, I had the joy (and sometimes awe and even frustration) of knowing him as professor, thesis advisor, mentor, critic, business partner and friend. In all this time I never once saw him diminish or shed the aura of his incredible scientific heritage and his scientific gravitas. It was part and parcel of his essence and his actions. Even when my wife and I would go on vacation with Michel and his lovely wife Marina and be gazing at an extraordinary Hawaiian landscape or sitting on the beach, we could feel that Michel's mind was on his science. He would never be without a good technical book — yes, even on Waikiki Beach! And this scientific intensity blended seamlessly with his Old-World demeanor, which was perhaps best expressed by one of his early Princeton faculty colleagues, Bill Schowalter, when he described Michel as "exuding European urbanity."[1] It was part of his persona.

It is, therefore, appropriate to start this account of Michel's life with a look at the extraordinary scientific patrimony he carried, going back many years before he was born in Brussels on June 18, 1924.

Michel's father, Franscoise Boudart, was a well-known chemical industrialist in Belgium, an early executive at UCB (Union Chimique Belge), as well as the founder and president of the Fédération des Industries Chimiques de Belgique. Not surprisingly, Michel became interested in chemistry. After graduating from secondary school, Michel was accepted to the University of Louvain. Because it was closed during WWII, Michel studied chemistry privately and when the University reopened in 1944 Michel entered the Chemistry Department and graduated in record time, with a BS in 1945 and a MS in 1947. His family urged him to complete his PhD in Belgium and join the ranks of the Belgian chemistry elite.[2] Michel had other plans: He wanted to study with Sir Hugh Taylor at Princeton.

Taylor had earned a PhD from the University of Liverpool in 1914, and during his studies spent a year at the Nobel Institute in Stockholm under the direction of Svante Arrhenius (1903 Nobel Prize winner for Chemistry)[3]. As we all know, the "Arrhenius Plot" has been part of the vocabulary — and the dreams and nightmares — of every catalytic chemist. It is fun to think that, as students of Michel, we had "two degrees of separation" from Svante Arrhenius himself! Shortly after Taylor received his PhD, he moved to Princeton and in 1919 wrote the first significant textbook on catalysis with Sir Eric Rideal. He traveled extensively, and one of his trips was to the University of Louvain where he was a visiting scholar in 1937[4]. While there, Taylor was made a Commander of the Order of Leopold II of Belgium, an honor bestowed to civilians who made "meritorious service to the sovereign of Belgium"[5]. It is not surprising that Michel knew of Taylor's work and was attracted to Princeton.

Michel headed to Princeton in 1947. This move defined the rest of Michel's life and, through him, the lives of so many of us. He could not have picked a more stimulating and exciting academic environment to shape his scientific and intellectual life, especially since it included not just the University but also the Institute for Advanced Study, which had attracted some of the greatest scientific minds of the times following the Manhattan Project. Michel and Marina took full advantage of their new home. Michel often talked about the informal weekly discussions of important topics attended by many Princeton faculty at the home of one of his Belgian friends (the equivalent of the European "kaffeeklatsch") and his experience attending (enduring) a violin performance by Albert Einstein to which he was invited – in Einstein's home!

Hugh Taylor shaped Michel's analytical, mathematical and, perhaps most importantly, molecular approach to research, and this has defined the technical thinking of all of us who see ourselves as his "scientific children." In addition to their scientific bond, Michel shared a strong personal bond with Sir Hugh, including their deep Catholic faith. Michel was a member of the Catholic Youth Club at Louvain, where he met his wife Marina. The Youth Club was led by a prominent Louvain nuclear physicist, Monsignor Luc Guillon, who had an important influence on Michel.[6] Hugh Taylor, also devoutly Catholic, was the prime mover of the establishment of a Catholic chaplaincy at Princeton in 1928. Michel and Marina were married in Sir Hugh's home on December 27, 1947.

Despite continuing pressure from his family to return to Belgium and join his father's company, UCB, after earning his PhD in 1950 Michel stayed on at Princeton.[7] He accepted a position as

[1] Private communication.
[2] Private communication.

[3] Kemball, C. (1975). "Hugh Stott Taylor 6 February 1890 – 17 April 1974". *Biographical Memoirs of Fellows of the Royal Society*. **21**: 517-547. p 517
[4] Kemball, C. (1975). "Hugh Stott Taylor 6 February 1890 – 17 April 1974". *Biographical Memoirs of Fellows of the Royal Society*. **21**: 517-547. p 520
[5] https://en.wikipedia.org/wiki/Order_of_Leopold_II
[6] Private communication.
[7] Private communication.

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Research Associate at the Forrestal Campus headed by Professor John Fenn (2002 Nobel Prize winner for Chemistry), who became a lifelong friend. In later years, Fenn often visited after Michel moved to Stanford, frequently interacting with his students there. Fenn also had an entrepreneurial bent, which later influenced Michel's involvement with my company, Catalytica, in the early 1970s. Michel was promoted to Assistant Professor in 1954 and to Associate Professor in 1958. He remained at Princeton until 1961, when he was invited to join the faculty of the Chemical Engineering Department at the University of California, Berkeley. Soon after, in 1964, he joined the Chemical Engineering Department at Stanford, where he would spend the rest of his significant professorial career.

At Princeton, Michel would soon make his mark as an analytical thinker able to take ideas from others and expand their impact and relevance. This can be seen with Michel's very first published paper, *Linus Pauling's theory of metals in catalysis*[8], in which he extended Pauling's correlation of metallic radii and percent *d* character of the metallic bond to catalytic activity of metal surfaces. This paper helped Michel launch one of the important concepts in catalysis, which has served as a cornerstone for many theories including the development of linear scaling relationships and the predictive theories for reactivity of metal surfaces. Eventually, Linus Pauling became Michel's lifelong friend and mentor, in part through the very close relationship between Michel and another pivotal member of the catalyst community, Paul Emmett, who grew up with Pauling in Portland, Oregon. Many former students fondly remember the lunch discussions with Linus and Paul on the deck at Michel and Marina's home at Stanford, when Linus would drill us with his clear and piercing blue eyes while Michel would enjoy these exchanges, twirling his ever-present mustache with a twinkle in his eyes.

In 1974, Michel supported two young entrepreneurs, Jim Cusumano and me, in conceiving and founding a company. Michel suggested we call it Catalytica. Michel and I had been talking for a few years about the possibility of forming a consulting firm. I had, by then, joined Exxon after earning my PhD in Michel's lab in 1972. Our interest in a consulting venture escalated with the Arab oil embargo of 1973. I had concurrently been talking about entrepreneurial ventures with my Exxon colleague and friend Jim Cusumano. The three of us decided to form Catalytica in mid 1974 and officially started business in November of that year. Michel's endorsement and dedicated support was clearly a pivotal element during our early years. Michel would open the door; Jim and I would close the sale — and do the bulk of the work. We rapidly attracted an incredible group of PhDs, several from Michel's Stanford lab. By the late 1970s, we employed about 50 PhD-level researchers and had a thriving consulting and contract research practice. Through Michel's influence, a number of academics agreed to serve on our Advisory Board and made great contributions to our science and our strategy. In the early 1980s, we made the shift to focus on our own proprietary ideas and by the late 1980s had a solid enough patent estate to form two subsidiaries: Catalytica Energy Systems, Inc. and Catalytica Pharmaceuticals, Inc. Catalytica Energy Systems leveraged the inventions of Ralph Dalla Betta, who had been Michel's student and was one of our earliest Catalytica team members. Some of Ralph's work is the subject of an article in this issue of *Journal of Catalysis*, highlighting Catalytica's advances in catalytic combustion. Catalytica Pharmaceuticals started as a research lab developing catalytic processes for more efficient manufacture of pharmaceutical building blocks. Eventually, the company flourished as a supplier of intermediates and the final active ingredients for numerous drugs marketed by the Pharmaceutical industry, and by the late 1990s had become a major supplier of final packaged drugs, with 2000 employees and several manufacturing sites in the US. In 2000, Catalytica Pharmaceuticals was acquired by Royal DSM. Michel's imprint of scientific rigor permeated Catalytica throughout its almost 30 years as an entrepreneurial venture.

Michel's full impact on the science of chemical catalysis is best represented by his almost 300 publications, many highlighted in this issue of *Journal of Catalysis*, along with the work of his many scientific children and grandchildren: 69 PhD graduate students who in turn extended Michel's academic legacy by graduating well over 10-fold PhD students of their own, and the legacy continues to grow. The scientific fabric that Michel embodied lives on in the new generations of researchers who honor the heritage of a long scientific tradition dating back to the early part of the 20th century. Today, we continue to benefit from Michel's attention to the elementary steps in the catalytic process, his insistence that data be normalized as the turnover frequency occurring on the active catalytic site, the consideration of microkinetic behavior at the surface, and the influence of rate limiting steps. It is the "Boudart School" of catalytic thought.

In addition to Michel's indelible scientific imprint, those of us who had the privilege of being his students were shaped by experiencing the man and his milieu. The precious one-on-one and intimate encounters Michel enabled with extraordinary scientific luminaries like John Fenn, Linus Pauling and Paul Emmett were only the tip of the iceberg. Michel's lifelong companion and social driving force, Marina Boudart, routinely catalyzed extraordinary gatherings at their home. It was commonplace for students and friends to be invited to their home for what was advertised as a small cozy get-together, only to enter a magical world with several dozen joyful guests. What was awe-inspiring was the mix of the participants, ranging from never less than three or four Nobel laureates, to the King of Belgium, (then Crown Prince Phillip) while he was a graduate student in Political Science at Stanford in the 1980s.

There was only one Michel Boudart. I am forever grateful to have shared a small part of the fabric of his wonderful life!

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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[8] *Pauling's theory of metals in catalysis,* Boudart, *J. Am Chem. Soc.* 1950, 72:1040.

[9] http://www.nasonline.org/publications/biographical-memoirs/memoir-pdfs/boudart-michel.pdf.