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INTERVIEW

Professor Ralph Sturgeon, a researcher with an extensive and very significant scientific and administrative career kindly gave an interview to BrJAC

Ralph Sturgeon received his Ph.D. in analytical chemistry in 1977 and has been with the National Research Council Canada since that time. His interests lie in inorganic analytical chemistry, comprising trace element analysis, vapor generation, organometallic speciation and production of Certified Reference Materials with a focus on atomic and mass spectrometry measurement techniques. He has published some 350 peer reviewed articles, a dozen book chapters and edited two books. He served as Editor for *Spectrochimica Acta Reviews* for 16 years, is a member of the advisory board of a number of international analytical chemistry journals and represented Canada's interests at the International Bureau of Weights and Measures where he participated in the working groups for both Inorganic Analysis as well as the Joint Committee on Traceability in Laboratory Medicine for 14 years. His contributions to the analytical sciences have been recognized through a number of awards and distinctions, including Fellowship in the Chemical Institute of Canada (1990) and the Royal Society of Chemistry (UK, 2012), the Barringer and Herzberg awards of the Spectroscopy Society of Canada, the McBryde Medal from the Chemical Institute of Canada, the Ioannes Marcus Marci award of the Czech Spectroscopic Society, the Maxxam Award of the Chemical Institute of Canada and the Lester W. Strock medal from the Society of Applied Spectroscopy (USA). Most recently, he shared an Outstanding Achievement Award from the NRC (2022) in recognition of work in mass spectrometry. He holds three patents relating to sample introduction for atomic spectroscopy.

BrJAC: How was your childhood?
Dr. Sturgeon: I enjoyed what I would say was a perfectly normal middle class childhood, but likely quite different from today's generation, as mom was always home and only dad went to work. My two brothers and I were thus well looked after but never spoiled, although our parents were always a bit excessive when it came to Christmas celebrations. On the negative side, dad was always seeking a more challenging job and consequently the family moved across Canada at approximately 4 year intervals which, until I entered high school, tended to interrupt development of long-term friendships. I have a sharp memory of my father taking home study correspondence courses in the evenings to broaden his ability to advance in digital electronics. This instilled a sense of importance of education in me and my brothers such that we always knew we were destined for postgraduate degrees. I know that dad was very proud of all of us and our achievements.

BrJAC: What early influences encouraged you to study chemistry? Did you have any influencers, such as a teacher?

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Dr. Sturgeon: I somehow gravitated to chemistry before I had finished grade school and my parents encouraged my interest by providing me with those famous home chemistry experiment sets when birthdays and Christmas rolled around. I augmented these by periodically purchasing typical laboratory wet chemistry equipment and reagents with savings of my weekly allowance. I was also reading the chemistry textbooks of my brother who was 4 years ahead of me academically, such that when I entered high school I basically already knew the curriculum. Fortunately, my grades 12 and 13 chemistry teacher nurtured my interest in chemistry by encouraging me to visit the chemistry lab after hours to conduct guided experiments. Of course, during those early years, like many young boys with a fascination with chemistry, I was really captivated by compounding black gunpowder from a variety of constituents and used it to achieve ever more larger explosions and launching tin cans to greater heights. In today's world I would likely have been watched by the authorities as a person of interest intent on undertaking destructive acts. My mind was thus made up when I entered high school that I would major in chemistry when I attended university.

BrJAC: How was the beginning of your career in chemistry?
Dr. Sturgeon: In retrospect, seemingly almost effortless! Following completion of my second year of undergraduate study in 1971, I enjoyed a summer research internship with my first real mentor, Prof. Chak Chakrabarti, at Carleton University. He introduced me to the fascinating field of ultra-trace inorganic analysis and the then cutting-edge technique of graphite furnace atomic absorption spectrometry. Working with a postdoctoral fellow from Jim Winefordner's Gainseville Florida laboratory, I earned a co-authorship on a publication in *Analytical Chemistry* and enjoyed first-hand exposure to a rigorous research environment. I recall the excitement and pride of this accomplishment, which carried me through a further two years of undergraduate studies to thereafter embark on postgraduate work exploring the fundamental mechanisms of atom formation in the graphite furnace. My years in the Chakrabarti laboratory were exceptionally productive and career building as they brought me into personal contact with most of the high profile international researchers in spectroanalytical chemistry of that era (1960's to1970's) *via* their visits to his laboratory or my attendance at national and international meetings.

Boris L'vov (Ottawa, 1999).

My Ph.D. research focused on mechanistic insights into atom formation in the graphite furnace…imagine my excitement spending several days with the "father" of GF-AAS, Boris L'vov, during our participation in the 1976 FACSS/XIX CSI in Philadelphia, having the opportunity to wander through the city with him, a visitor from St. Petersburg Russia during the cold war era! We became lifelong friends and exchanged visits to each other's laboratories in later years. I will admit, that of those I came to know, Gary Hieftje remained particularly inspirational to me throughout my career because of his tremendous presence/influence in analytical spectroscopy, exemplary career and his unpretentious and enthusiastic approach to his science and interactions with others.

Before I graduated with my PhD in analytical chemistry, I was fortunate to have two job offers without formally applying for either of them. Prof. Chakrabarti insisted that his students present their research at national and international conferences. This exposure was far more impactful than completing anonymous job application forms. Both positions were essentially permanent, perhaps something rare in today's job market, either by choice of by employer necessity. One was to enter the private sector accepting an invitation from Walter Slavin to join the Perkin-Elmer Corp. in Norwalk CT, USA to aid in the development and application of atomic absorption instrumentation; the other was to take up a research associateship position with Shier Berman which held a tenure tracked future with the National Research Council of Canada in Ottawa. To make a long story short, I eventually decided on the NRC position and have fortunately never imagined a reason to look back with any remorse. I was given free-reign to conduct independent research in any area

of analytical chemistry that held my interest provided I also contributed to establishing what would become Canada's future chemical metrology institute. In this connection, I was tasked with development of some of the world's first certified reference materials to support marine chemistry research…..subsequent versions of these are still on the market today used as quality control materials in numerous international laboratories and may resonate with some users/readers: NASS-1, MESS-1 and PACS-1 CRMs were released in the early 1980's. This dichotomy of work left me challenged and exhilarated for decades, looking forward to returning to work every Monday morning.

Susan Hieftje, Gary Hieftje, Vahid Majidi and Ralph Sturgeon (Loen, Norway, 2012).

BrJAC: What has changed in your profile, ambitions, and performance since the time you started your career?

Dr. Sturgeon: In short, almost everything, as should be expected. Over the course of time you need to evolve and move with the flow of scientific developments or you quickly become irrelevant. As mentioned above, I began my career as a research associate but charged with maintaining a balance between fundamental and applied research. As such, my initial career was like that of any new researcher and for me, this was to establish myself as an independent expert in a prevailing area of fundamental atomic spectrometry and trace element analysis. We focused on novel methods of matrix separation and targeted element extractions/preconcentration, designing closed FI systems and synthesizing immobilized solid phase extraction media to minimize contamination and sample handling. This was coupled with a number of early developments in microwave assisted digestions, both closed vessel, on-line and vapor phase techniques. After some 15 years at the NRC, I had accomplished these initial career goals and transitioned from a predominant interest in AAS to plasma based sources. My aims in this area focused on sample introduction and the development of complementary plasma based techniques, such as FAPES and DBDs. In the mid-1980's we had developed an efficient means of undertaking quantitative sequestration of generated hydrides in a preheated graphite furnace, employing reduced platinum group elements to effect their dissociative chemisorption onto the added metal. This simple approach, ultimately marketed as an accessory by instrument companies, enhanced limits of detection by GF-AAS some 100-fold for these elements. This naturally also led to exploration ETV with vapor generation as a sample introduction methodology to enhance detection power for both ICP-OES and -MS techniques.

Apart from personal objectives, there was a need to fulfill a more general goal that was associated with a public good or group oriented mandate. As earlier noted, this was to contribute to the development

of Certified Reference Materials to support Canada's marine communities of scientific research. This endeavor remained a constant backdrop throughout my career and ramped up in the latter years. By the mid-1990's, the changing focus of the NRC coupled with the international demands of free trade, laboratory accreditation and the need for traceability in analytical measurements (as well as in many other fields of measurement), more fully shifted the emphasis of work in our group to alignment with that of global National Metrology Institutes such as NIST and IRMM, a move to more deeply focus on metrology. During this time period I was tasked with leading our group of about 15 researchers and technicians, which became a daunting administrative undertaking as this required managing a budget of over $1 million (excluding salaries) to support purchase of new instrumentation, maintenance, consumables, travel and postdoctoral positions as well as staff mentoring and career development. This was very demanding of my time as I was also determined to keep a presence in the laboratory as an active researcher. I held this position for some 12 years, which turned out to be the most rewarding period of my career. I represented the NRC as our Canadian National Metrology Institute at the International Bureau of Weights and Measures, serving on the Inorganic Analysis Working Group and the Joint Committee in Laboratory Medicine during this period. These activities heavily immersed us in international metrology activities and the adoption of laboratory accreditation, necessitating international blind sample comparative analyses as well as reciprocal auditing of similar activities in other NMIs. By 2015, I (or was it perhaps my wife?) decided that it was time to wind down some activities and retire. This I did, but fortunately received an NRC presidential (lifetime) appointment as an emeritus research officer, affording me continued access to the analytical laboratories and fulfilling collaborations with my immediate colleagues as well as other international researchers. Life and careers evolve and after nearly 50 years at the NRC mine is still in a state of progress; I have not lost my fascination for research, problem solving, education and the fulfillment gained from working with others.

BrJAC: What are your lines of research? You have published many scientific papers. Would you highlight any?

Dr. Sturgeon: As a succinct summary, my interests have already been briefly presented in the earlier introduction. As such, both fundamental (particularly relating to mechanistic process in the graphite furnace) and applied research (i.e., method development and validation) areas have been targeted, more recently against a backdrop of metrology. We have enjoyed a number of "firsts" as regards publications/recognition in these areas, which provides a great deal of satisfaction and feeling of relevance amongst peers. Some 45 years ago, we produced the world's first suite of marine Certified Reference Materials comprising seawater, fish and sediment matrices whose iterations are still in prominent use today. We initiated the first development of practical techniques for trapping and pre-concentrating volatile metal hydrides in a graphite furnace as well as a mechanistic understanding of the process, resulting in uptake of this approach by major instrument companies as an accessory device. We have contributed to the first applications of solid phase microextraction for concentration and detection of organometallic species by atomic spectrometry and provided some of the first CRMs for speciated forms of elements such as arsenic, mercury and selenium in environmental matrices. We advanced early work on microwave digestion techniques, including continuous flow systems and vapor phase approaches for ultimate control of reagent blanks.

Significant work and time in later years have been devoted to understanding and expansion of analyte vapor generation techniques, including both classical chemical as well as photochemical means to enhance sample introduction efficiency for atomic and mass spectrometries. These studies provided the first evidence of production of "volatile" transition metal species from a tetrahydridoborate reducing medium and the opening up of a completely new field of fundamental study and applications of photochemical vapor generation of transition and noble metals as well as semi-metals and the halogens which is being actively pursued today.

From the perspective of chemical metrology, perhaps our most significant contribution has been supporting its international advancement and uptake through activities relating to the Mutual Recognition Arrangement globally signed in 1999 by National Metrology Institutes. This provided a structure wherein NMIs participated extensively with the BIPM coordinating exercises on blind inter-comparisons to evaluate the inter-comparability of their measurement capabilities and thus the traceability of international standards in chemistry. As well, we served to audit international laboratories for their compliance with required ISO operating standards. In this regard I had the privilege of representing the NRC for more than a decade at the BIPM, serving in the inorganic chemistry working group, the joint committee for traceability in laboratory medicine and subsequently as the rapporteur for the the Consultative Committee for Amount of Substance: Metrology in Chemistry and Biology (CCQM). These were significant times for the growth and influence of the CCQM and a most memorable time for our contributions as historic redefinitions of the mole and kg were undertaken in 2018 to define them on the basis of fixed numerical values of the Avogadro and Planck constants, respectively. Amongst only a few NMIs, we participated in the high accuracy/precision determination of the atomic weight of Si, which contributed to an accurate measurement of both constants.

It goes without saying that an acknowledge of the significant input of co-workers and external collaborators to many of these projects is needed, without whose support the rate of advancement and likely the span of the research projects would not be as broad.

BrJAC: For you, what have been the most important recent achievements in analytical chemistry research? What are the landmarks? What has changed in this scenario with the COVID-19 pandemic?

Dr. Sturgeon: Firstly, I don't believe that anything significant has changed as a consequence of the past pandemic, other than perhaps a diminished perception of the veracity of science in the eyes of the general public, which will have to be re-earned. Chemical research necessitates the presence of scientists in dedicated laboratories. Although there was definitely an impact at the time which impaired the progress/speed of new research, as many laboratories completely closed or were minimally utilized, I think we have returned to a "normal" pre-pandemic state over the past two years, evidence of which is the return of scheduled in-person scientific conferences.

"For me (and likely others of my age cohort) it is fascinating to see the rapid evolution of personalized medicine...I feel I had the 'misfortune' of being born 25 years too early!"

Second, this is a very broad set of questions and I will reply with correspondingly broad comments. As we all appreciate, analytical chemistry involves identifying and quantitating substances in every arena in which chemical measurements are undertaken. It thus plays a critical role in the global economy: ensuring fair trade of commodities, material processes/industrial control, forensic investigations, environmental monitoring, food safety, biological and medical activities as well as sustainable energy (ranging from a hydrogen economy to development of fusion reactor materials). Capabilities continue to evolve, wherein measurements have typically become faster, less expensive, more precise and accurate, traceable and internationally comparable, serving to open up new areas of discovery with evermore sophisticated tools and techniques. We need only to scan the most recent issues of any journal devoted to the analytical sciences to appreciate the tremendous advances that sample preparation techniques and novel instrumental approaches to analyses have made. Perhaps the most remarkable are those connected with the health sciences - disease diagnosis and treatment, development of point of care capabilities, microfluidic-enabled wearable biosensors geared towards personalized medicine, and the environment - monitoring of global warming as well as contamination control and remediation in all spheres.

For me (and likely others of my age cohort) it is fascinating to see the rapid evolution of personalized medicine…I feel I had the "misfortune" of being born 25 years too early! Diagnostic testing, discovery of biomarkers for disease, targeted drug delivery systems based on nano-platforms, printing scaffolds for working organs, biocompatible materials, 2- and 3-D imaging of cells and organs revealing the interactions

within and between cells at unprecedented levels of information, insights into disease markers, all promising dramatic changes in the direction and capabilities of health care on the horizon. These developments have obviously been brought about by advances in biochemistry, chemistry, nanotechnology, mass spectrometry and, likely more so in the future, increased use of non-targeted approaches to discovery. Development of new nano-catalytic materials opens additional directions for detection platforms as well as enhanced industrial materials syntheses and potential energy generation *via* photoelectrochemical catalytic processes. Of necessity, all entail measurements of chemical species and/or their structures, relying on analytical chemistry.

The continuous evolution of mass spectrometers offers broader ranges of application due to ever higher throughput, enhanced detection power, improved resolution and increased freedom from interferences, providing pronounced analytical capabilities at decreasing cost. Together with innovative sample preparation, new chromatographic techniques, varied and more efficient sample introduction (ambient techniques associated with a wide range of plasma sources) and chemical tagging approaches, leveraging of a more complete understanding of important biomolecules has become feasible. Despite the steady encroachment of MS-based approaches into the domains typically occupied by optical spectrometry, interest in these techniques continues unabated and I am intrigued by the myriad developments in biophotonics and associated nanotechnologies, specifically the synthesis of selective and sensitive nanostructures incorporating chemical reagents for detection of ultralow concentrations of analytes ranging from complex organic and organometallic species to trace metals, often facilitated by SERS and TERS effect Raman detection as well as nanoparticle enhanced LIBS. These developments, coupled with more powerful computers to rapidly digest vast arrays of signal information subjected to data sorting using neural network AI and chemometric processing will leverage significant information from ever smaller samples (such as single cells) to expand the omics revolutions and provide a more holistic approach to the understanding of many systems.

In my own areas of research, I would highlight our modest contributions to improving trace element detection power by increasing sample introduction efficiencies for optical and mass spectrometries. This has focused on both improvement and expansion of existing methodologies which employ chemical and electrochemical reduction of semi-metals and several transition metals, as well as development of new and more powerful approaches based on photochemistry, leading to generation of volatile forms of transition and noble elements as well as the halogens. The practical application and fundamental mechanistic investigations in this field are both novel and enormously interesting.

BrJAC: There are, in Brazil and in the world, several conferences on chemistry. To you, how important are these meetings to the chemistry scientific community?

Dr. Sturgeon: I would maintain, as would many like-minded researchers, that scientific meetings are productive and useful, and have been for many years; the first-ever international scientific conference took place in Karlsruhe, Germany in 1860 with the aim of clarifying many of the basic tenets of chemistry of that era. Face-to-face public discussions, and those that take place in more unstructured, private settings associated with formal meetings are notable for their productivity and advancement in acceptance of ideas, despite availability of modern instantaneous digital communications networks. Moreover, personal exchanges in real time often catalyze collaborative interactions, resolve subtle points of contention or lead to new paradigms/ideas more rapidly than *via* any other medium of communication. I thus see conferences as a complimentary vehicle to publication, a means of advancing research at a rapid rate, especially providing graduate students and younger researchers with the ability to meet leaders in their field and to acquire a better grasp of enhanced scientific communication skills.

If by this question you meant specifically how important are meetings in Brazil to their chemistry community, I might comment that it was not until 1988 that I made my first visit to South America to participate in the “First Rio Symposium on Furnace Atomic Absorption Spectrometry”, in Rio de Janeiro. This had ostensibly been organized with the underlying goal of addressing a problem at that time, namely

the significant difficulties South American researchers experienced participating in international meetings. The solution was to bring this particular meeting to Brazil. It was entirely successful and began a (to this day) continuing series of biennial meetings moving throughout South America, fostering numerous scientific collaborations and exchanges of information and staff. This ultimately provided opportunities for Brazilian researchers to access the typically better equipped foreign laboratories to pursue their studies and help mentor their next generation of graduates.

Some international guests at the 16th Rio Symposium (Bento Goncalves, Brazil), L-R: Rodolfo Wuilloud (Argentina), Heidi Goenaga-Infante (UK), Ralph Sturgeon (Canada), Marcia Foster Mesko (Brazil), Jan Kratzer and Jiri Dedina (Czech Republic), Ewa Bulska (Poland), Ryszard Lobinski and Johanna Szpunar (France), Patricia Smichowski (Argentina) and Érico Marlon de Moraes Flores (Brazil).

BrJAC: What is the importance of awards for the development of science and new technologies?
Dr. Sturgeon: I would like to believe that rapid advancements in science and technology would continue unabated, even in the absence of potential awards, as individuals would remain productive, driven by their quest for answers to all manner of questions and the innate desire to excel. Findings would continue to be presented at conferences and heralded as publications in international peer reviewed journals. That being said, recognition of outstanding performance does serve to bolster pride in ownership of discovery as a consequence of peer recognition of achievements and they certainly are frequently (perhaps unfortunately) used as a career metric in many circles of employment opportunity and may influence success rates for awarding of research grants. However, I am not aware of any researcher purposely embarking on a career path that includes milestones anticipating receipt of an award.

BrJAC: What advice would you give to a young scientist who wants to pursue a career in chemistry?
Dr. Sturgeon: Let's start with an old adage…. *work hard* …but love what you do…explore subjects you enjoy; "work" should hopefully be one of your hobbies and not just a job… which if you are successful will unfortunately be why you may have to get used to the idea of no retirement. In this connection, be aware of where your strengths and interests lie. There are many fields of chemistry to study, ranging from organic, inorganic, physical, bio- and analytical. Further sub-disciplines include theoretical/quantum chemistry, electrochemistry, geochemistry, radiochemistry, astrochemistry and chemical kinetics; find your niche but don't be afraid to change at any time. Many successful scientists have moved through several iterations of themselves over their careers, following their evolving interests.

As for establishing an active research program, ideas and topics generally start with personal interests and are curiosity driven, but may be imposed by an employer's agenda and should/could arise by discerning where the relevant problems are by consulting the literature and examining popular conference themes, taking influence from the direction of peer research and recognizing that there is lots of room for research in "applied" areas of analytical chemistry. Lastly, keep an open mind and acceptance to adventitious opportunities that may pass your way.

"Don't be afraid to fail, but do try again. Don't avoid risk taking when your research results suggest something that may go against the currently accepted or perceived notion of your peers, but be open and do use due diligence to avoid confirmation bias."

Read widely and broadly; stay Informed by continuously educating yourself on new developments and be aware of trends (in analytical chemistry). Science is a multidisciplinary endeavor, you never know where or how a new idea may arise or when a complimentary field may stimulate thoughts for new explanations/experiments. As noted, don't be afraid to change research direction periodically.

Collaborate whenever and as often as possible. The universal truth of John Donne's famous expression in his poem "For Whom the Bell Tolls", *i.e*, "no man is an island", continues to resonate on this, its 400th anniversary. Through (multidisciplinary) collaborations with internal and external colleagues, much can be learned, and quickly, by interacting with experts in other areas who may also have needed instrumentation that may rapidly move an idea forward due to the synergy of the process.

Don't be afraid to fail, but do try again. Don't avoid risk taking when your research results suggest something that may go against the currently accepted or perceived notion of your peers, but be open and do use due diligence to avoid confirmation bias. Keep in mind that reviewers may favor established methodologies or perspectives, potentially stifling innovative or unconventional ideas and, by extension, your scientific progress.

Take all opportunities to attend scientific meetings when they are presented to you; networking and putting your face forward are great ways to build your scientific career.

Be prepared to take on administrative duties when your turn comes; someone earlier took such responsibility to shelter you in your earlier development years from time consuming paperwork. Such positions, as well as those serving on various committees or groups offer additional opportunities for personal growth and interactions which may yield profound insights into your own character as well as more opportunities for collaboration and ideas.

Finally, and specifically, analytical chemistry can certainly be a challenging profession precisely because it has such a far ranging impact on so many fields of science.

BrJAC: For what would you like to be remembered?

Dr. Sturgeon: From a scientific perspective….. perhaps as a role model…someone who impacted or influenced the career of a student or researcher to some degree, whether that be as a result of direct mentoring or publication of a body of research that had been sufficiently interesting to stimulate their ideas and contribute to and cultivate their approach to research and publication….and further, that I was committed to upholding a sense of ethics, fairness, sharing and openness.

From a non-scientific perspective….as a helpful and dependable friend to anyone I have interacted with and enjoyed sharing time with.