L. Cronin

Leroy (Lee) Cronin

Date of birth:	June 1, 1973
Position:	Gardiner Professor of Chemistry, Head of Research, EPSRC Advanced Research Fellow, Royal Society/Wolfson Foundation Merit Award Holder, University of Glasgow (UK)
Education:	1994 BSc, University of York (UK) 1994–1997 PhD (DPhil) with Prof. P. H. Walton, University of York 1997–1999 Postdoc with Dr. N. Robertson, University of Edinburgh (UK) 1999–2000 Alexander von Humboldt Research Fellow with Prof. A. Müller, University of Bielefeld (Germany)
Awards:	**2005** EPSRC ARF, **2006** European Young Chemists Award (Silver Medal), **2006** Nexxus Young Scientist Award, **2007** Philip Leverhulme Prize, **2008** Morino Foundation Lectures, **2009** Fellow of the Royal Society of Chemistry, **2009** Elected to the Royal Society of Edinburgh, **2009** Royal Society/Wolfson Foundation Merit Award
Current research interests:	Fundamental projects are based around understanding the mechanism of assembly of functional nanoscale POM clusters, designing new molecular nanoscale architectures, exploring complex and emergent chemical systems, networked reactions (chemical nets), nonequilibrium assemblies, self-growing nano/micron-scale structures, and dissipative chemical systems. I am also trying to develop research into "inorganic/artificial biology", aiming to shed light on the emergence of life from the inorganic world and molecular evolution outside of biology. Applied science projects underway in the laboratory are based on catalytic/electronic applications of metal oxides, small-molecule sequestration/activation, and fabrication of complex inorganic materials and systems by using sophisticated molecular-cluster precursors.
Hobbies:	Running, cycling, learning to sail, playing with technology, red wine

*L. Cronin has recently published his **25th article** since 2000 in Angewandte Chemie:*
"Modular Inorganic Polyoxometalate Frameworks Showing Emergent Properties: Redox Alloys": J. Thiel, C. Ritchie, H. N. Miras, C. Streb, S. G. Mitchell, T. Boyd, M. N. Corella Ochoa, M. H. Rosnes, J. McIver, D.-L. Long, L. Cronin, *Angew. Chem.* **2010**, *122*, 7138–7142; *Angew. Chem. Int. Ed.* **2010**, *49*, 6984–6988.

My ultimate goal is to … assemble/discover artificial (inorganic) biology.

When I was eighteen I wanted to be … a fast jet pilot.

The biggest problem that scientists face is … funding fundamental science in an economically constrained world in which politicians/research bodies measure scientific progress by immediate "application" outputs.

My biggest inspiration is … my research group members.

If I were not a scientist, I would be … unemployed, or maybe a mechanical engineer.

My biggest motivation is … curiosity, and the wish to try to do something new.

The secret of being a successful scientist is … being optimistic and critical in (almost) equal measure.

In ten years time I will be … 47 (and who knows, during this time I could watch England win the football world cup? On second thoughts …).

The best advice I have ever been given is … "The most successful academics are defined by their capacity to survive failure".

The part of my job which I enjoy the most is … having creative ideas, and trying to convince others to implement them.

A good work day begins with … a coffee and a crazy idea.

My favorite book is (at the moment) … "Zen and the Art of Motorcycle Maintenance: An Inquiry into Values" by Robert M. Pirsig.

My worst habit is … imagining that there is more time in a day than there really is.

How is chemistry research different now than it was at the beginning of your career?

The pace of chemistry research has increased dramatically during the last decade. Not only is the amount of research being done/published increasing dramatically, but the time to publication has also decreased. The amount of available literature data, with the plethora of databases and electronically searchable journals, has also transformed the area (allowing historical data to be included). Improvements in technology have transformed analytical techniques, and this all adds to the increase in speed that advances can be made, especially in the elucidation of complex nanoscale architectures. All these aspects, combined with the increase in interdisciplinarity for the field, means that chemistry research is now more exciting and fast-paced than ever.

Has your approach to chemistry research changed since the start of your career?

At the start of my career I was very focused upon molecular design/synthesis of molecular systems and correlating design with function and overall properties in a rather simplistic manner. Now I like to try and take a more holistic/systematic approach to chemistry research and my work tends to focus on complex molecular systems. The result is that we employ far more analytical techniques and engineering approaches to molecular chemistry than previously. In terms of discovering/understanding new phenomena this is really important because complex systems call for very careful experimental analysis that requires multiple controls and comparative experiments, as well as an open mind and creative ideas. Still, the very good synthetic foundations I received have been absolutely fundamental for these studies.

Has your approach to publishing your results changed since the start of your career?

Our approach to publication has changed during the last few years, mainly as a result of the problems we are tackling and the number of experiments/techniques we are using. The main challenge for us is the need to present the “big picture” to place the research in context, especially for the work we send for publication at more general chemistry/science journals. Of course, this requires a very delicate balance between keeping the narrative clear whilst ensuring sufficient detail is present to allow colleagues to judge, repeat, and build on the work. In this respect the use of electronic supporting information is extremely helpful and I anticipate major further developments in this area. In fact, we are trying to produce an online supplementary data link to our web-listed publications, for example, 3D rotatable crystal structures (see our website http://www.croninlab.com/).

What do you think the future holds for your field of research?

Chemical synthesis is undergoing a revolution fueled by new techniques, approaches, and the wish to make ever more functional and sophisticated molecules and molecular systems. As a chemist I am inspired by the self-regulating and autonomous nature of biological systems and I am fascinated by the prospect of devising minimal “living” inorganic systems. Even if this is slightly too fanciful (although by definition I like to suggest provocatively that the origin of life must have been inorganic), I am sure that developments in complex/systems chemistry in nanoscale inorganic systems is going to be a tremendously exciting area. Certainly the combination of complex self-assembling and self-organizing systems could lead to new ways of making, using, and designing molecules/nanomolecular architectures and systems that have been previously out of reach.

Have you changed the main focus of your research throughout your career and if so why?

During my career we have been gradually employing more analytical techniques to help understand the synthesis and structure of our molecules and the self-assembly process across all length scales. This has required us to move from being synthetic chemists to physical and materials scientists. This has been really exciting. Right now we are shifting our focus again from “one-pot” molecular synthesis to “multiple-pot” networked synthesis and this is forcing us to learn much more about kinetics, chemical engineering, and reaction modeling.

What has been your biggest influence/motivation?

The burning desire to do my own research, to conduct cutting-edge science, and to discover new chemistry has long been a huge ambition and motivation. However, without a doubt my mentors, collaborators, research group, and colleagues have all had defining roles, influenced my approach, educated me, and also suffered my often ill-thought-out and crazy ideas. One of the things I like most and what motivates and influences me, is the wish to take part in scientific discourse to explore new ideas. In fact, my modus operandi is often to reveal/throw open my ideas and to have them criticized by people that I respect and admire.

What advice would you give to up-and-coming scientists?

Do something different, have crazy ideas, and try and aim for the stars. Seek the critical advice of your peers and do not ignore their advice—true critical advice is a very precious commodity. Be free with your ideas and not too possessive—often an idea shared is an idea doubled.

What is the secret to publishing so many high-quality papers?

Be creative, focused, aware of the literature, and stand by your convictions. It is vital to write the work as clearly as possible and to ensure that you get nonspecialists to read your work before submitting the paper, as well as experts you admire to give you proper criticism. Above all, good ideas and careful experiments can lead to unexpected results that are normally far more interesting than the ones you expect. In this respect the secret, if there is one, is having an open mind and a willingness to recognize and to follow up unexpected discoveries.

L. Cronin has been featured on the cover of Angewandte Chemie:
“Reversible Redox Reactions in an Extended Polyoxometalate Framework Solid”: C. Ritchie, C. Streb, J. Thiel, S. G. Mitchell, H. N. Miras, D.-L. Long, T. Boyd, R. D. Peacock, T. McGlone, L. Cronin, *Angew. Chem.* **2008**, *120*, 6987–6990; *Angew. Chem. Int. Ed.* **2008**, *47*, 6881–6884.

My 5 top papers:

1. “Unveiling the Transient Template in the Self Assembly of a Molecular Oxide Nanowheel”: H. N. Miras, G. J. T. Cooper, D.-L. Long, H. Bögge, A. Müller, C. Streb, L. Cronin, *Science*, **2010**, *327*, 72 – 74.
   The mechanism of the self-assembly of gigantic molecular nanostructures is fantastically difficult to elucidate, especially when the synthetic system is a one-pot system. In this paper we describe the use of a flow-reactor system to trap the transient template that appears to “nucleate” the assembly of a gigantic 3.6 nm diameter {Mo_{154-x}} molybdenum blue wheel. We were also able to crystallize this intermediate under the conditions of the flow reactor, which allows the modulation of the charge on the ring, in turn leading to the transient host–guest complex {$Mo_{36}\subset Mo_{154-x}$}. The realization that we were able to use the flow system to trap the transient template, which is solely responsible for the spontaneous self-assembly of the nanowheel, and hence presenting a mechanistic rationale is important because until this work any understanding of the mechanism seemed far from reach.
2. “Spontaneous Assembly and Real-Time Growth of Micrometer-Scale Tubular Structures from Polyoxometalate-Based Inorganic Solids”: C. Ritchie, G. J. T. Cooper, Y.-F. Song, C. Streb, H. Yin, A. D. C. Parenty, D. A. MacLaren, L. Cronin, *Nature Chemistry*, **2009**, *1*, 47 – 52.
   In this paper we show how crystals of inorganic materials (in this case a metal oxide) can be refabricated by using an unprecedented process to construct micrometer-scale hollow tubes with controllable diameters, which “pump” the ionic material away from the crystal and lead to self-fabrication of the structure. These tubular structures are robust, have vast aspect ratios, and are electronically active. The direction of growth can also be controlled to allow the design and construction of real devices based upon the polyoxometalate-based tubes. Of course, this was discovered by chance—we were trying to uptake some dye into the “open” frameworks present inside the crystals, and instead, before our eyes, the crystals grew tubes. This was a rather exciting moment in the laboratory.
3. “Probing the Self-Assembly of Inorganic Cluster Architectures in Solution with Cryospray Mass Spectrometry: Growth of Polyoxomolybdate Clusters and Polymers Mediated by Silver(I) Ions”: E. F. Wilson, H. Abbas, B. J. Duncombe, C. Streb, D.-L. Long, L. Cronin, *J. Am. Chem. Soc.* **2008**, *130*, 13876 – 13884.
   In this paper we examined the self-assembly of cluster architectures and polymers by using electrospray and cryospray mass spectrometry, and we showed that it is possible to follow the reaction from the building blocks into the structure and fragments of the structure. These studies offer an experimental approach to “directly” probe the self-assembly process, and also allow a qualitative kinetic analysis. In fact, it is possible to use mass spectrometry to monitor both the reaction mixture (building up) and the dissolved crystals of the polyoxometalates (breaking down), which gives extremely useful comparative data that was not accessible before.
4. “Reversible Redox Reactions in an Extended Polyoxometalate Framework Solid”: C. Ritchie, C. Streb, J. Thiel, S. G. Mitchell, H. N. Miras, D.-L. Long, T. Boyd, R. D. Peacock, T. McGlone, L. Cronin, *Angew. Chem.* **2008**, *120*, 9687 – 6990; *Angew. Chem. Int. Ed.,* **2008**, *47*, 6881 – 6884.
   In this paper we present a pure inorganic polyoxometalate open framework (POMOF), which incorporates heterometal linkers within the fused “modular” building-block units. The crystals of this material can undergo single-crystal to single-crystal redox transformations, which result in a net oxidation-state change for the whole crystal. This is the first time that reversible single-crystal to single-crystal redox transformations have been reported in any material class. This is interesting because this material is modular and a whole family of isostructural frameworks can be assembled in which the electronic properties of the framework and the inner cavities can be precisely defined. This may have consequences for designing electronically active “zeolite”/MOF-like materials.
5. “Restraining Symmetry in the Formation of Small Polyoxomolybdates: Building Blocks of Unprecedented Topology Resulting from ′Shrink-Wrapping′ $[H_2Mo_{16}O_{52}]^{10-}$-Type Clusters”: D.-L. Long, P. Kögerler, L. J. Farrugia, L. Cronin, *Angew. Chem.* **2003**, *115*, 4312 – 4315; *Angew. Chem. Int. Ed.,* **2003**, *42*, 4180 – 4183.
   This manuscript presents a very simple, yet key discovery in our work: cation-exchange reactions involving organocations can be used to access totally new types of nanoscale molecular architectures. This paper acted as the defining text and motivation for at least 30 other papers from our group and others that reinforced and expanded the concept of cation control in the synthesis and self-assembly of polyoxometalate architectures, possibly even allowing the design of new cluster architectures from the bottom up. This work also convinced me that we needed to start to seriously consider other techniques such as mass spectrometry and NMR spectroscopy to investigate the mechanism of self-assembly. For me, it is interesting to look back on this paper because we had no idea at the time how pivotal the result was to be, but I am just fascinated and enthralled by the new science we have been able to do directly as a result of this publication.

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