BREATHING LIFE INTO INORGANIC ALIEN MATTER

by Lee Cronin

Our laboratory was established at the University of Glasgow in 2002 as the complex chemical systems laboratory. I was appointed to the Regius Professor of Chemistry in 2013 and today my team is one of the world's largest chemistry-focused research teams.

I have wanted to explore chemistry using electronics to control matter since the age of 9 when I got a ZX81 computer and a chemistry set and after becoming frustrated that I could not connect them together. This is because I wanted to understand how to control matter from the bottom up. Ever since I could remember, I have been interested in understanding why we are here, why life exists, and what life is. It seems to me that there is a fundamental disconnect between our understanding of fundamental physics, chemistry, and biology; this is because these systems become more and more complex the further you get from physics to biology. However, many physicists, anxious not to lose the complexity bandwagon, also got involved in the area of chaos theory which highlighted to me that classical physics, as well as quantum mechanics, suffered from uncertainty. When I was 18 years old, I became convinced that the one big problem that needed to be solved was figuring out how life started on earth. Put literally: how does the dead or inorganic world become living? How is sand transformed into cells? Today, my entire research team is set up to explore this grand aim.

I made a number of observations when I was setting my team up to look at the search for the origins of life, or how to make life from scratch in the laboratory. First, I reasoned that the origin of life is in fact a 'big chemistry problem'. The issue is that doing experiments by hand in the laboratory was going to be hard; the origin of life also appeared to require a lot of experiments. It is thought that life emerged 'quickly' on earth, perhaps in less than one hundred million years. That would require a lot of chemistry experiments! A radical solution was needed to address this problem: we needed to digitize chemistry. To address this moonshot, we built the team around four main aims: the construction of an artificial life form; the digitization of chemistry; the use of artificial intelligence in chemistry including the construction of 'wet' chemical computers; and the exploration of complexity and information in chemistry. Our recent work on the digitization of chemistry has resulted in a new programming paradigm for matter and organic synthesis and discovery – chemputation – which uses the world's first domain-specific and universal programming language for chemistry – XDL[1]. My team designs and builds all of their own robots from the ground up and the team currently has 25 different robotic systems operating across four domains: organic synthesis, energy materials discovery, nanomaterials discovery, and formulation discovery. All of the systems use XDL and are easily programmable for both manufacturing and discovery. My group is organized and assembled transparently around ideas, avoids hierarchy, and aims to mentor researchers that use a problem-based approach. Nothing is impossible until it is tried.

My role in the Madonna project involved the construction of digital-chemistry-robots that could discover new reactions for biological systems and to engineer ways of embedding these new reactions in biological systems. The idea here was to find the correct language to allow the robots, chemical, and biological systems to interact with each other. The language of biology is not only genetic, but kinetic and spatial. The language of chemistry is molecular, with concentrations and kinetics, and the language of robotics is digital programming. Interfacing these systems together was one of the Madonna project's biggest challenges.

I was very happy to host an artist in my laboratory as I thought it would be a good way to communicate the efforts going on in the laboratory, the big picture, and the way science is done across big teams that are unified by a single grand vision. The artist, Isabelle Andriessen, first gave an online lecture to our group about her work and we had a discussion about the teams' work before her arrival. When she visited, she interviewed me several times and also spent time talking to various members of my team finding out about their research, exploring the robotics, looking at data, the architectures of what we were building, and so on. This was helpful as a very

[1] For more info, you can visit: XDL-standard.com.

important aspect would be that the artist could help to develop a common language or visual that would capture the vision and allow both the team and the outside world to see how we are exploring the problem of making a new life form. The first question that we had to understand was perhaps even harder than aiming to make life: What is life? I mean, really, what is life – we all think we know it when we see it, but do we? A key issue is that if you ask 10 people to define life, then you will get at least 10^2 answers as a point-by-point list of vital characteristics. This narrative does not lend itself to a well-contained argument. To solve this, we have managed to find a way to define life by finding a unique thing that all living things do – but could I explain this to anyone, and could this be captured for the non-scientist?

The key insight that I needed to explain, as a chemist to a non-chemist, is that life, or living systems, have the unique ability to make complex molecules in large amounts. The focus on the molecules is good since if living systems can make molecules so complex that they could not possibly form by chance, then could we make a complex molecule detector? Would this be a life-detector? We have developed a new approach to counting molecular complexity by using a machine called a mass spectrometer in order to rank how complex a molecule is. A mass spectrometer can weigh the molecule and can tell you how many unique parts it has; it is also possible to count the total number of molecules.

Now that we have a life-detector, can we now build an origin of life, or artificial life, 'search engine'? This is the main project that is underway in my lab at present. We are literally designing one of the biggest and longest chemistry experiments ever planned. The system will be able to search trillions upon trillions of reactions, looking in many different environments, but will we find the spark of life? It was great that Isabelle visited our laboratory during the design and building phase of the experiments.

My own background in art is on the visual side, where I spend a lot of time developing ways to explain our ideas and approach. This can take the form of technical drawings, conceptual diagrams, and movies. As a hobby, I have even explored encoding imagery into digital oscilloscope art and composing music inspired by our science. This art is very dynamic because the pictures are encoded into the music, so the pictures emerge and are dynamic when the waveform is plotted by the oscilloscope. I was very interested to compare and contrast this approach with the artist. To my surprise, I found my approach more 'emotional', exploring a creative space with not too much meaning whereas I found the approach of the artist to be also emotional, but with much better methods and also a clearer set of intentions. This intentionality is exciting since it will ensure that the artist is able to explicitly encode a lot of meaning into the art being produced. I am also excited because I think the use of interpretive art as a medium to convey science ideas, new findings, theories, and questions is highly important and has the potential to widen participation and to inspire the imagination.

The artist, Isabelle Andriessen, visited our laboratory as we were designing and building our robotic laboratory for the exploration of the origin of life/the discovery of artificial life. My team moved into the new Glasgow Advanced Research Centre in February 2022. This is the biggest purpose-built facility for digital chemistry in the world and houses a vast array of robotic equipment and state-of-the-art chemical analysis tools. The residency was tough to set up because of our conflicting schedules coming out of COVID-19, but we were able to develop an interesting set of ideas that explored the possibilities of using a combination of online and real time visits. The artist shadowed part of my team and conducted interviews asking team members about their research, aims, and expectations.

I think that the collaboration with Isabelle was amazing because her interest in the re-animation of dead materials and understanding the death-to-life transition was a key overlap between us. I think that her views on the nature of this critical transition – what happens when the living becomes dead and when the dead becomes living is a critical question for science and more generally culture. What happens to living information after it dies? Does it disperse? Is it lost? Does the information created in one life live on in others? The initial creation, a movie, and a narrative about the robotics in the laboratory searching life, the prospect for life conveys the mystery and the expectation of the discovery.

My view of the process was that it was extremely dynamic. Although I only spent a limited amout of time with Isabelle, I found that my feelings and anticipation of the discovery, the meaning of the research, and the bigger picture were reflected in the encounters we shared. It was almost as if we had swapped roles, with me being the artist interpreter of the science, and Isabelle being the scientist questioning the world. This reflective interaction is something that I like to do in science because reality is not some fixed or some static quantity; reality is shaped by our interactions with each other, with the world, and is also modulated by our sensors and views or biases.

Now that the visit is over, I am excited to see the outcome, but I am also mindful that Isabelle was only with us for such a short time and that our project is still going. The short film produced is very powerful in terms of the visuals, the narrative, and the way in which the heartbeat of the laboratory was captured. It made me feel that the experiments and the animation via the robotics was starting to breathe life into the inorganic robots.

Will we manage to build a new lifeform from scratch anytime soon? Could this event be captured and explained by future interactions with artists-in-residence? Should we attempt to document, explain, and engage with the public through expressions of art? I think that the answer to all of these questions must be yes. Understanding the process of life is vital, if we are ever going to understand if there is life elsewhere in the universe, to understand the origin of life on earth, and also to understand the future of life on earth, humanity, and our culture.