What is Life?
How Chemistry Becomes Biology
Addy Press
Oxford University Press, USA, 2012
ISBN: 978-0-19-964101-7
Pages 256, $ 21,95

Kinetics to the rescue

In his new book, *What is Life? How Chemistry Becomes Biology*, Addy Pross takes on perhaps the most difficult scientific question ever posed. This question is exactly as the title of the book reads, and it has remained frustratingly out of our grasp for decades, perhaps centuries. The problem starts with the definition of life itself. Others have enumerated the myriad definitions that have been proposed over the years, and the first two chapters of *What is Life?* adroitly summarize these and bring the reader up-to-date on them ... and on their shortcomings. The central issue can be distilled down to a tug-of-war between reductionist and holistic views of the living process. Each works up to a point, but neither is completely satisfying upon complete scrutiny. To move past this standoff, something else, some new approach is needed.

In the remainder of the book, Pross makes the case that a *systems chemistry* viewpoint has the potential to allow a complete and predictive description of life. To expound this argument, the book (to me) reads as though one were listening to the adagio from J.S. Bach's *Concerto for Two Harpsichords and Strings in C Minor*: it winds slowly and gracefully ever upward from first principles of chemistry and biology, to a detailing of how these are related, and then to the origins of life itself. The prose is doggedly self-referential, making sure the reader has make all the necessary connections before moving on to the next point. The argument builds gradually until, as in Bach's *Concerto*, it seems to break through the clouds with a single epiphanistic note. That note is *kinetics*, *i.e*, rates of change, which is the underlying principle that can tie chemistry to biology and give the latter the handle that science so desperately needs to grasp it.

To bring an appreciation of the heft of kinetics in illuminating what life is, the book devotes much space to the notion of stability, an in particular to the distinction between thermodynamic stability and kinetic stability. The former is static stability, and is the type most often imagined when thinking of how change in Nature takes place. Transformations proceed, within the restrictions of the laws of thermodynamics, to more stable states. But the latter is perhaps unique to life. In some circumstances there can be a dynamic kinetic stability, or DKS, where the persistence of the system as a whole is maintained through constant change. This apparent contradiction is not so crazy, or unusual, as Pross explains. DKS is in fact the type of steady-state situation that self-replicating systems (read: crudely, *life*) share in common.

Making hay out of the idea of a dynamic stability among components of a collection of entities is facilitated by a relatively new field of study called systems chemistry by its champion, Günter von Kiedrowski. *What is Life?* skillfully explains how this approach to investigating chemical reactions *en masse*, and with a focus on the population rather than the individual, allows us to extract the best that reductionist and (bottom-up) and holistic views (top-down) have to offer. In many ways systems chemistry can fulfill the promise that systems biology has of yet to bring to science. What systems chemistry can offer us is a set of observations – later engrained into rules – that allow predictions of how systems of molecules increase in complexity over time. Argues Pross, isn't that exactly what we want to describe the evolutionary progression of life?

This complexification of matter is at the heart of two phenomena that *What is Life?* strives to unite: the chemical origins of life and the subsequent evolutionary diversification of living organisms. The latter is indisputably guided by the process of natural selection. The centerpiece of this book is that natural selection itself is an outcome of DKS-driven events. If evolving and ecologically robust chemical systems can be explained by their tendency towards dynamic kinetic stability, then by extension all life can. This is because there is no magic boundary between chemistry and biology.

I will repeat that last sentence to put it in the spotlight that Pross has shone; there is no magic boundary between chemistry and biology. This resonates true. However to best appreciate this, one is forced to examine prebiotic chemistry, the events that led from non-life to life on the Earth some four billion years ago. Pross is forceful in making the distinction between this field of study, which is the pursuit of what he terms *historical principles* and systems chemistry *per se*, which is the pursuit of *ahistorical principles*, *i.e*., the general rules that govern how life can exist, as opposed to how it specifically happened to come about on the Earth. While Pross is, in my estimation, a bit too rough on the value and latent power of historical prebiotic chemistry, he does give the reader a wake-up call that in some sense what did happen on our planet is less important that how it could have happened. This is definitely food for thought.

In the end, Pross proposes the following new definition of life: *a self-sustaining kinetically stable dynamic reaction network derived from the replication reaction* (p. 164). This definition will enter the ring of hungry lions and only time will tell if it survives. I feel, though, that it has a good chance of becoming firmly established in science despite its likely intractability to the general populace. Each word in the definition, as Pross states, is carefully considered to create a consistent whole. Life is in fact, an ever-changing set of interactions among components that are continually tested for their reproduction speed. This can apply to molecules in a test tube, bacterial cells festering in a wound, and seals sunning themselves on a shoreline.

What is Life? is a fascinating and insightful read. The book is well illustrated with evocative analogies and clear descriptions of key experiments that have been performed over the years that bear on the issue of the chemical nature of life. It has utility and enjoyment value to readers from a wide variety of backgrounds. I imagine that it will be read by many people who will come away with the important points that life not only possesses a rapidly changing sameness, but that this is not such a strange contradiction after all.

Niles Lehman
Department of Chemistry
Portland State University
Portland, OR, USA