Between the bud and the rose

The Rainbow and the Worm: the Physics of Organisms

by ***Mae-wan Ho****, World Scientific, 1993. £25.00 (xiii + 202 pages) ISBN 981 02 1487 1*

Take a cell. Or a TV set. Or a laser. Place it in a liquidizer and homogenize. Subject the suspension to gradient centrifugation and further separate the pieces by electrophoretic or chromatographic means. Study the properties of the pieces. Then physically or intellectually reconstitute the original system. If you believe that this is the way to understand how a cell or a TV set or a laser works, and especially if you do not, then you should read this book.

Just half a century ago, the physicist Erwin Schrödinger sought in his eponymous book to answer the question 'What is life?', by asking whether the properties of living systems might be explained in terms of the physics and chemistry then known. Although he concluded that they could not, he believed it likely that they would be as knowledge advanced, and, indeed, we now know, from developments in the understanding of thermodynamically open systems, that the essential nonequilibrium character of living systems can at least be understood satisfactorily from a macroscopic energetic point of view.

The simplistic but traditional lists of biological properties that are often used to distinguish living from nonliving (such as the ability to reproduce or to grow or to respond to stimuli) all fail when challenged by obvious counterexamples (nuclear fission, crystals, computers), let alone in the case of cryptobiotic or dormant states such as spores. For 'big' questions there are no easy answers, and thus most philosophically motivated but scientific enquiries of this type which, as with the present book, seek to answer the big question of what life is, rightly begin by looking in a fairly coarse-grained way at some of the fundamental physical and chemical principles that are relevant for life. For Mae-wan Ho, and for your reviewer, life is not a thing but a process, of organized, dynamic complexity: 'being alive is to achieve the long-range coordination of astronomical numbers of submicroscopic molecular reactions over macroscopic distances.'

To understand what this means requires that we examine carefully why living systems, as isothermal molecular energy converters, do not contravene the second law. For this, Maxwell's Demon must be successfully exorcized, since our molecular energy machines are constantly fighting the thermalizing influence of the heat bath in which they are surrounded, equilibrium with which would lead to the loss of any stored 'free' energy and thus the inability to perform useful work. The Demon is vanquished, and we turn to mechanisms by which such molecular-scale activity can lead to the emergence of macroscopic order; here Bénard convection, the Belousov–Zhabotinsky reaction and other examples are used to illustrate how molecular reactions obeying quite simple dynamic equations do lead naturally to the macroscopic behaviour observed.

The important concept, then, is of coherence, in which many millions of molecules condense into a collective quantum state, exemplified in physics by phenomena such as superconductivity, superfluidity and stimulated emission within lasers. Especially for the latter, Morowitz's famous dictum applies: the flow of energy through a system acts to organize that system. At low input energies the laser acts like an ordinary tungsten lamp; excited atoms emit light randomly. As the input power is increased above a threshold, all the excited atoms then oscillate and emit together. Could it be, then, that systems of this type can give us useful clues about the organization of living systems? Of course it can, else we should not have dwelt here.

The late Herbert Fröhlich developed the idea that long-range, collective excitations of this type were indeed the hallmark of living systems; they are thus systemic properties, so that what Clegg calls the 'cataclysmic violence of homogenization' must inevitably remove the essential character of living systems, which is of a high-level spatiotemporal, dynamic organization. We are reminded of the Heisenberg uncertainty relations, and of Schrödinger's cat – how then are we to study this exquisite organization without destroying it? Clearly, noninvasive methods are needed, and Dr Ho describes in detail why she believes that the phenomenon of biophoton emission studied over a number of years by Popp may constitute one of the more hopeful approaches for characterizing these coherent organizational states *in vivo*. Stimulated further by this approach, Dr Ho has invented a novel method for observing intact living systems using a special type of polarizing microscope; the idea is that coherence in the organism should be reflected in a long-range order which, as with various types of liquid crystalline materials, might manifest as subtle changes in birefringence. With her new microscope, the coruscating dynamic organization of living systems is revealed in its full, technicolour glory, waxing and waning with developmental stages, and changing reversibly upon chilling. Here are the rainbow and the worm of the title.

Finally, to the more philosophical. To Bohm's implicate order, in which subsystems are enfolded within each other to make systems. To Whitehead's organicism, Haken's synergetics, Time's arrow, and organisms as coherent space–time structures. This is not whimsy, but the outpouring of the author's obvious erudition and deep enthusiasm for her subject.

What then have we learned since Schrödinger? That we *can* begin to approach the complexity of living systems in terms of physics and chemistry: not the physics and chemistry of equilibrium and of linear expansions of force–flux relations, but the physics and chemistry that is needed to deal with complex systems, involving nonlinearities and nested hierarchies of dynamically interacting subsystems, which lead to collective, emergent properties, one of which is life.

Should you read this book? If you are interested in serious thinking about the nature of living things as systems, then without question you should read it, for it is an excellent introduction to the more physically motivated approaches to understanding biological complexity. And there's not a gel in sight.

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