Artificial Life
An Overview
Ed. Christopher G. Langton
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Robotics, neural networks, genetic algorithms, computer viruses, self-organization ..... - the readers of the Journal of the Indian Institute of Science will recognize these as some of the most exciting and vibrantly active research fronts. As a smart marketing strategy, these (and a handful of others) are now being packaged and advertised under the brand-name "Artificial Life". A sustained and vigorous advertising campaign, this one. The proceedings of an international workshop were brought out under the name "Artificial Life" in 1989. This was followed by "Artificial Life II" in 1991-92, and in due course, by AL III and AL IV. Inevitably, a journal "Artificial Life" made its maiden appearance in 1994. The first three issues of this journal have next (in 1995) been put together (and sold for $29.95) as "Artificial Life : an overview", which is the book under review.

A one line summary for readers with very short attention spans (are there any others?) - an interesting and useful collection of articles, though calling all of them 'artificial life' seems very contrived, at best.

What is "Artificial Life" all about? One cannot do better than quoting from the lucid and eloquent introduction by the editor-in-chief Christopher Langton - " .. an attempt to increase vastly the role of synthesis in the study of biological phenomena ..". The two most striking things about the living world are its complexity and diversity. Understanding the regularities, laws or theories behind these has been (and continues to be) a cherished goal of scientists. So far, the emphasis has been on analysis - a detailed study of the various living systems. A parallel, and equally (if not more) rewarding approach would involve constructing their analogues. Insights gained during such attempts would add considerably to our understanding of life. Langton's example of chemistry brings out the point much more clearly and forcefully - Chemistry advanced both from the analysis of the structures of natural products, as well as from the syntheses of a large number of their variants. "To have a theory of the actual, it is necessary to understand the possible".

In the opening essay of the book, " Artificial Life as a tool for Biological Inquiry", Charles Taylor and David Jefferson methodically put forward the four levels of biological organization (molecular, cellular, organismic and population/ecosystem) and the three distinct approaches used for modelling them. The 'Wetware System' involves chemical reactions between biomolecules, the 'Software system' simulates cellular/intercellular phenomena as well as populations and ecosystems, and the 'Hardware system' (generally mobile robots) that mimic various organisms. The authors follow this up with a section impressively titled 'Open Problems in biology amenable to study by artificial life modelling' - and this is where one begins to notice a false note or two! The open problems mentioned by them include topics such as cultural evolution, origin and maintenance of sex and structure of ecosystems; things which evolutionary biologists have been investigating for decades using the standard techniques of population genetics. It is not at all clear as to what is accomplished by relabelling the whole exercise as artificial life. The feeling of uneasiness is further strengthened by the next article "Co-operation and Community Structure in Artificial Ecosystems" by Kristian Lindgren and Mats G. Nordahl, which opens with " artificial ecologies consisting of artificial organisms are likely to become useful tools for understanding general principles of how ecological communities are organized". Likely to become? What they call artificial ecologies of artificial organisms is scarcely different from the simple mathematical models (e.g. the famous prey-predator Lotka-Volterra system) known to biologists for over half a century. More than thirty years have elapsed since W.D. Hamilton used 'artificial ecologies of artificial organisms' for making a pioneering contribution towards a genetical theory of social evolution, and about fifteen years since Robert Axelrod and W.D. Hamilton used the iterated prisoners' dilemma game to explain the evolution of co-operation. Let me make clear once again that I do not dispute the importance of the authors' findings; these could make welcome contributions to say the Journal of Theoretical Biology and its other illustrious cousins. It is the continued and pretentious peddling of this stuff under a new name "Artificial Life", that makes it difficult for me to refrain from lashing out.

Many of the subsequent chapters fall into the same category. P. Schuster describes the progress made since 1970s, when Spiegelman introduced the RNAs (Ribonucleic Acids) based "evolution in a test-tube", and followed by Eigen and co-workers' hypercycle models. The idea of the 'shape space' for RNA molecules, described by Schuster, represents a truly monumental contribution - demonstrating how, despite the astronomically high number of different (10^{60}) alternative possibilities, a random (mostly inactive) sequence of RNA could, with as few as 20 odd mutations, transform into a functional, active molecule with a correct shape. To the persistently nagging question of whether there has been enough time for life to have originated *and* evolved on the earth, this finding leads to the first substantially satisfactory response.

As expected, the fashionable fields of fractals and cellular automata make their appearance, complete with the very pretty computer graphics (P. Prusinkiewicz). Can chaos and complexity theory be far behind? Kunihiko Kaneko describes an ingenious example (evolution of imitation of bird-songs) using the edge-of-chaos paradigm. E.W. Bonabeau and Guy Theraulaz handle phenomena as diverse as the recruitment of antibody-producing clones and nest-building activity in wasps, with effortless ease. (Their opening remarks on how one can justify working on artificial life are a delight to read). Michael G. Dyer of computer science department, UCLA gives a crisp, up-to-date, clear and comprehensive summary of the various aspects of animal behaviour. As a fifteen page guide on animal behaviour for non-biologists, this is unlikely to be surpassed. The most incisive comment (a mandatory warning to be pasted on the desktop of every artificial life researcher) comes from the authoritative and comprehensive chapter on genetic algorithms by Melanie Mitchell and Stephanie Forrest : "It is difficult to distinguish between 'yet another cute simulation' and systems that teach us something important and general, either about how to construct artificial life or about the natural phenomena that they model. We suggest that artificial-life research should address at least one of these two criteria and that it is important to be explicit about what any specific system teaches us that was not known before".

While there are other fascinating chapters (e.g. computer viruses as artificial life by Eugene Spafford, artificial life roots of artificial intelligence by Luc Steels), let me conclude by describing the *piece de resistance.* "An evolutionary approach to synthetic biology: Zen and the art of creating life" by Thomas S. Ray, the legendary creator of Tierra (the software simulator of virtual life), can be regarded as the foundation stone of the true science of artificial life. To illustrate the clarity of expression, depth of thinking and breadth of vision of this essay, here is a quotation from the abstract: "Our concepts of biology, evolution, and complexity are constrained by having observed only a single instance of life, life on earth. A truly comparative biology is needed to expand these concepts. Because we cannot observe life on other planets, we are left with the alternative of creating Artificial Life forms on the earth. I will discuss the approach of inoculating evolution by natural selection into the medium of the digital computer. This is not a physical/chemical medium; it is a logical/informational medium. Thus, these new instances of evolution are not subject to the same physical laws as organic evolution (e.g., the laws of thermodynamics) and exist in what amounts to another universe, governed by the "physical laws" of the logic of the computer. This exercise gives us a broader perspective on what evolution is and what it does".

Can all this serve any useful purpose? Ray raises a tantalizing speculation. The newer, faster parallel computers are notoriously difficult to program. Furthermore, they can be most profitably harnessed by generally using them for computationally tough problems. The task of developing reliable and efficient software for this purpose is truly formidable. Ray's imaginative answer is 'digital husbandry'. This involves allowing artificial 'living' programs to interact and evolve on the parallel computers, and then 'selectively breeding' them, so that we gradually get more and more efficient and successful programs for specific tasks (exactly the way high-yielding varieties of rice, or cattle, are developed). Fantastic? Certainly so. Impossible? Only time will tell. But this certainly looks like an attractive road to march along.

On the whole, this book is a valuable collection of interesting articles, and the e-mail addresses of the authors (for the first time I've seen in any book) make it particularly easy for anyone to get in touch with them - and keep track of the latest developments in this fast-moving field (I hear that the conference Artificial Life V has recently been held)

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