

Preface

This proceedings volume of Artificial Life X marks two decades of research in this scientific community, a period marked by vast advances in both the life sciences and information technology. When Chris Langton launched the field in 1987 with the first *International Conference on the Synthesis and Simulation of Living Systems* at the Los Alamos National Laboratory, he proposed an alternative methodology to study life. Since biology is focused on the carbon-based chemistry of life as it exists on Earth, which it typically approaches with an analytical methodology, artificial life was proposed to concentrate instead on uncovering the fundamental principles of life via the synthesis of life-like processes in computers and other artificial media. Of particular interest are general principles of organization such as natural selection, self-organization, self-reproduction, learning, and collective behavior—all of which play a role in evolution, development, immune defense, intelligence, and social organization.

The synthetic methodology of artificial life is strongly based on the study of organizational principles of life as information processes, typically emerging from the dynamics of many simple interacting components. In the two decades since its inception, this methodology and its powerful set of tools have successfully leaked into other domains, including biology. Indeed, artificial life has contributed to the advancement of our understanding of the ways in which information is utilized in living and social organizations, and has also highlighted the distributed nature of these systems. Two decades after the first conference on artificial life, it is now almost commonplace to encounter studies of networks and other systems-level characteristics of biological and social systems published in leading scientific journals.

While the methods and tools of artificial life have been adopted in more traditional domains, artificial life remains an independent and well-grounded research endeavor. Naturally, the search for general principles of life needs to accommodate new knowledge about the molecular machinery of life on Earth. For instance, as we begin to measure more efficiently how networks of genes organize in biology, researchers in artificial life begin to investigate how abstract networks of genes can produce essential mechanisms of life, such as biological clocks. This research leads us to understand what is essential about gene networks in order to produce certain mechanisms, traits, behaviors, and even diseases. Using the same example, instead of studying the specific biochemical machinery of biological clocks, artificial life is concerned with the general principles of networks which can produce them.

It is therefore extremely rewarding to notice the variety of interdisciplinary subjects addressed by the articles accepted for publication in this volume, and how they similarly seek to understand the general principles of various processes in biology, cognition, and social

behavior. We received 112 submissions to this conference; 35 were accepted for oral presentation, and 47 for poster presentation. While the papers selected for oral presentations were chosen for their higher-impact potential, both types of papers are published in this volume without differentiation. Like all Artificial Life volumes before, we are certain that among the published articles there are important breakthroughs for the field and beyond. Undoubtedly, the field will continue to contribute fundamentally to our understanding of life itself, while producing novel solutions to complex real-world problems—from disease prevention to innovative robot designs and game theory—across science, technology, and human society. The next two decades of artificial life research will certainly bring exciting new achievements for what is now a mature field.

With the future of artificial life in mind, we decided to spotlight a specific theme on each day of the Artificial Life X conference: *computational biology*, *complex systems and networks*, *embodied cognition*, and *achievements and open problems in artificial life*. We chose the first three themes as areas where we observe much activity both in artificial life and throughout science in general, thus increasing the opportunities for fruitful interdisciplinary crossover. The fourth highlighted theme naturally stems from the need to discuss the achievements of the field in its two decades of existence, which this conference marks. Accordingly, we organized the articles published in this volume in subsections pertaining to one of these four themes:

1. ***Computational biology***: bio-networks, development, evolution, and prebiotic evolution and artificial chemistry
2. ***Complex systems and networks***: information and complexity, collective behavior and population dynamics, evolutionary and collective games
3. ***Embodied cognition***: embodiment and behavior, language and learning
4. ***Achievements and open problems***: biologically-inspired computing and technology, philosophy and formal models

To further spotlight these themes, we invited several outstanding keynote speakers working in these areas—some working within artificial life and some outside. From biology, we invited António Coutinho and Clyde Hutchinson III to highlight their work in immunology and synthetic genomics, respectively. From complex systems and networks, we invited Dirk Helbing to present his work on multi-agent simulation and Ricard Solé to speak on the discovery of universal patterns of organization in complex systems. From embodied cognition, we invited Cynthia Breazeal to speak on human-robot interaction and Hod Lipson to present his research on fully automated robot replication. Finally, to present their views on the achievements and open problems in artificial life, we invited Douglas Hofstadter and Norman Packard. We are extremely honored that such a distinguished group of scientists graciously accepted to participate in Artificial Life X.

Perhaps the most important component of a scientific conference are the members of its program committee, who review and ultimately select the articles that get to be presented and

published. We are greatly indebted to the members of the program committee who, even with an exceptionally short review window, helped us review all submissions with great attention and care. We list here the names of this outstanding group of scientists:

Chris Adami	Inman Harvey	Rolf Pfeifer
Fernando Almeida e Costa	Jesper Hoffmeyer	Daniel Polani
Randy Beer	Michael Huhns	Jordan Pollack
Richard Belew	Phil Husbands	Vitorino Ramos
Eric Bonabeau	Takashi Ikegami	Steen Rasmussen
Cynthia Breazeal	Srividhya Jeyaraman	Santiago Schnell
Mathieu Capcarrere	Hiroaki Kitano	Cosma Shalizi
Leandro Nunes de Castro	Jeffrey Krichmar	Linda Smith
Peter Cariani	Kristian Lindgren	Olaf Sporns
Jorge Carneiro	Barry McMullin	Luc Steels
Andy Clark	Melanie Mitchell	Hideaki Suzuki
Ernesto Costa	Filippo Menczer	Tim Taylor
Kerstin Dautenhahn	Jose Mendes	Christof Teuscher
Yiannis Demiris	J.J. Merelo	Peter Todd
Ezequiel Di Paolo	Alvaro Moreno	Jon Umerez
Claus Emmeche	Slawomir Nasuto	Richard Watson
Arantza Etxeberria	Chrystopher Nehaniv	Janet Wiles
Carlos Gershenson	Stefano Nolfi	Peter Wills
Ramon Grima	Charles Ofria	Andy Wuensche

There is no doubt that at Indiana University, Bloomington there is a substantial group of researchers intimately involved with Artificial Life. In particular, the School of Informatics, the Cognitive Science Program, and the Biocomplexity Institute consider Artificial Life an integral part of their research agenda. We are thus extremely honored to host Artificial Life X at the Indiana University campus in Bloomington. The organization of the conference in Bloomington was only made possible by the generous support received from the School of Informatics, whose administration was very excited and supportive of the idea from the very beginning. We are fully indebted to the Dean of the School of Informatics, Michael Dunn, for being so sympathetic to bringing Artificial Life X to Bloomington, and to Jim Buher, the School's Chief Financial and Facilities Officer, for working out the financial support for this endeavor. We are also very grateful for the support received from the Cognitive Science Program at Indiana University, whose chairs, Richard Shiffrin and Rob Goldstone, were equally enthusiastic about hosting the conference in Bloomington. Finally, another major institutional sponsor was the International Society of Artificial Life, whose president, Mark Bedau, happily embarked with us on this project.

The idea to bring Artificial Life to Bloomington originated with Fil Menczer, whom we have to thank for the encouragement to pursue it and for keeping us very busy in the past year! We

are also very happy to acknowledge the work of Mary Catherine Morgan at IU conferences whose professionalism and good nature has made this whole process so much easier. Likewise, we were very lucky to count on Titus Brown to once again develop the submission and reviewing software for this conference. His permanent accessibility and pleasantness went far beyond the call of duty. Others who were instrumental in the organization of this conference were Susan Quin, Assistant Dean and Director of Communications at the School of Informatics; Mike Cagle, the artist who crafted the illustrations used in the conference poster, web site, and on the cover of this volume; Bill English, who designed the web site; Markus Creasy, who maintained the site; and Valerie Geary and Robert Prior at the MIT Press for coordinating the publication of this volume.

We trust that this volume captures the excitement, creativity, and excellence of the field. The articles herein represent the research portfolio produced by a community which currently spans the entire globe. Since the first workshop in Los Alamos, we have witnessed the artificial life research program take hold in various research centers around the world. We welcome the reader to this community and the community to Bloomington where we will celebrate two decades of artificial life!

The organizing Committee of Artificial Life X,

Luis M. Rocha (Chair)

Mark Bedau

Dario Floreano

Robert Goldstone

Alessandro Vespignani

Larry Yaeger