Preface

The quest to apprehend the world in terms of the modular organization of its parts has an impressive track record in the sciences. Its roots reach back at least to the Scientific Revolution (the heliocentric conception of the cosmos). It includes Leibnizian and Kantian faculty psychology, Gall's phrenology, and nineteenth- and early twentieth-century debates in physiology and genetics, among many other relevant developments. This is just what one would expect, since modularity abounds in nature. Moreover, human art and engineering, as well as mathematics, crucially rely on modular *design* principles in their constructions. The instances of modules that the *New Webster's Dictionary and Thesaurus of the English Language* (1992) lists are from architecture, electronics, rocketry, and mathematics.

At present, modularity is a prominent theme mainly in the life sciences (including the neurosciences), cognitive science, and computer science (modular architectures). In biology, structural and functional modules are now recognized at many levels of organization. Their diversity urges for precise characterizations in their respective domains as well as the identification of commonalities and differences. In cognitive science and linguistics, a lively debate on "mind modules" was spurred by Jerry Fodor, and the interdisciplinary field of evolutionary psychology is grounded on the controversial "Swiss army knife" model of perception and cognition. Modularity also remains a central concept in the neurosciences, where new anatomical, imaging, and experimental methods make possible the identification of brain modules at various levels of granularity.

With some rare exceptions, discussions of modularity to date remain largely confined to the "home disciplines" (developmental and evolutionary biology, evolutionary psychology, etc.) in which they originated. The editors felt the time was ripe to bring together experts in the fields of—in alphabetical order—artificial life, cognitive science, developmental and evolutionary biology, economics, evolutionary computation, linguistics, mathematics, morphology, paleontology, physics, psychology, and theoretical chemistry, as well as philosophers of biology and mind, to try to

1. Survey the variety of disciplinary contexts in which "modular thinking" in general (e.g., hierarchical organization, near decomposability, quasi-independence, recursion) or more specialized concepts (e.g., character complex, gene family, encapsulation, mosaic evolution) play a role

2. Clarify, against this background, what modules are, why and how they originate and change (develop, evolve), and what this implies for the respective research agendas in the disciplines involved

3. Bring about a useful knowledge transfer between diverse fields regarding the broad topic of modularity wherever this appears useful and feasible.

To achieve these aims, the fifth Altenberg Workshop in Theoretical Biology, "Modularity: Understanding the Development and Evolution of Complex Natural Systems," was convened in the Lorenz mansion in Altenberg, Austria, in October 2000. Twenty-one participants discussed these and related issues intensively during four days. At the end of the meeting, the general feeling was that it had been very successful in that the first and third of our ambitious objectives were largely met, and that substantial progress was made regarding the second, and arguably the most difficult, objective as well. The (often multiauthored) papers that had been prepared for the workshop were rewritten, often substantially, in the light of our sometimes heated debates. This volume presents the results to the reader. A companion Web site containing a plethora of graphical materials that could not be included in the book is available at www.kli.ac.at/mit/modularity.

The editors thank the board of directors of the Konrad Lorenz Institute for Evolution and Cognition Research (KLI) in Altenberg, Austria, for its financial support of the workshop. We owe special thanks to the chairman, Prof. Gerd B. Müller, and the general manager, Dr. Astrid Juette, without whose logistic and moral support our task would have been much less agreeable. We warmly thank our 26 contributors and the staff at MIT Press, in particular Robert Prior, Valerie Geary, and Katherine Almeida for all their work and patience with the long gestation of the final manuscript.

Finally, with much pain in our hearts we learned in February 2001, three months after the workshop was held, that Prof. Herbert A. Simon had died in Pittsburgh at the age of 84. Because of his careful thoughts on the near decomposability of complex systems as well as much of his other work, Herb undoubtedly deserves to be called the master of modularity thinking. He had declined our invitation to participate in the workshop, not because of the physical stress involved in traveling but because he felt he had so much important work to finish. Instead, he gently offered to send us a manuscript to read, assuring us that his thoughts would be with us. After his death, Herb's family kindly granted us permission for this manuscript (dated September 29, 2000) to be included as the foreword in the present volume. We dedicate this book, imperfect as it is, to the memory of this great man, in the hope that as a "satisficer," not as an optimizer, he would have enjoyed it.