8 Conclusions

Within fifty to a hundred years a new class of organisms is likely to emerge. These organisms will be artificial in the sense that they will originally be designed by humans. However, they will reproduce, and will evolve into something other than their original forms; they will be "alive" under any reasonable definition of the word … The advent of artificial life will be the most significant historical event since the emergence of human beings.

James Doyne Farmer (1992)

Artificial Life (AL) is a new and rapidly growing research field. AL combines multidisciplinary attempts to explain complex phenomena in Nature by using new procedures – typically a synthetic (i.e. bottom-up approach) and computer simulations. Thus, AL helps understand complex phenomena that can not be explained by using more familiar linear models.

AL has three main goals: studying biological issues, abstracting principles of intelligent behavior and develop practical applications based on those findings. In doing so, AL uses computational techniques to understand biological issues and biological techniques to solve computational problems. Referring to the connection between AL and biology, AL can be characterized as the study of human-made systems that posses some essential characteristics of living systems.

Another way to describe AL is that it tries to give solutions to high-level problems by understanding low-level rules. Computer simulations show that complex patterns and complex behavior emerge from the application of simple local rules to small units and from the simultaneous interaction of several of such units at a lower level. Expressed with few words, one could say that: "the sum is often more than its parts." Another important finding of artificial life research is that there is no need for central organization or control, in order to have complex behavior, since behavior emerges from the low-level rules themselves.

Examples of pattern formation in natural and artificial systems using simple rules are cellular automata, Lindenmayer systems (L-systems), and fractals which can be used to explain the growth-process of plants and the formation of patterns on seashells and to develop artificial creatures in the game of life.

A similar result – the emergence of complex behavioral patterns – can be seen in robots and natural agents. In this context it is also called "distributed" or "swarm intelligence." Through a process of mutual interaction, self-organization and interaction with the environment, artificial and natural agents achieve impressive results they would never be able to achieve on their own. Good examples are self-organizing phenomena in insect societies (how bees organize their nest or how ants find the shortest path to a food source), the flocking of boids (a computer simulation of birds), or the heap building process of some robots (Didabots). Self-organizing artificial societies and agent-based models can also be used to understand and solve complex real-world problems such as distribution of resources, market predictions and data-mining. Again no central control is needed.

Another important topic in the broad research field of AL is artificial evolution. There are four main types of evolutionary algorithms: genetic algorithms, evolutionary programming, evolution strategies, and genetic programming. These types have been developed at about the same time but with different goals in mind. The application of artificial evolution, i.e. to get a wide variety of new solutions and offspring respectively, to evaluate their fitness and to allow only the best solution or the fittest offspring to reproduce, leads to new and unexpected results. Methods from artificial evolution as optimization procedures, or more generally as design methods have proven very useful. Using evolutionary algorithms, solutions have been found that humans could not easily have derived.

One limitation in AL is that it is mostly based on computer simulations and models. Thus, its findings are not restricted to those of traditional biology but to the possibilities of computers. Despite the fact that simulations and models used in AL lead to new and unexpected results (that often cannot be predicted because too many interactions take place simultaneously), they depend on how the simulations or models are designed and what data is fed to the computer. Simulations and models always have to simplify the world and cannot fully reflect real-world situations. Another limitation is that results have to be interpreted and that such interpretations strongly depend on the intention and the background of the interpreter. One way to set aside such restrictions, is to connect AL and its findings to the real world, e.g. by building robots which have to interact with, and learn from, the physical world, rather than by designing agents and environment on a computer.

AL is a rapidly growing branch of science that introduces new means and methods to find new solutions to existing problems. Thus, it helps to gain a deeper theoretical understanding of existing biological knowledge and to formulate new ideas that can be applied to other fields of science and real-world problems.