ALife and Society: Editorial Introduction to the Artificial Life Conference 2016 Special Issue

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Artificial life (ALife) research is not only about the production of knowledge, but is also a source of compelling and meaningful stories and narratives, especially now when they are needed most. Such power, so to speak, emerges from its own foundations as a discipline. It was Chris Langton in 1987 who said that "By extending the horizons of empirical research in biology beyond the territory currently circumscribed by life-as-we-know-it, the study of Artificial Life gives us access to the domain of life-as-it-could-be […]" [1, p. 1]. The very notion of life-as-it-could-be opened up many possibilities to explore, and released the study of life from its material and our cognitive constraints. The study of life did not have to be limited to carbon-based entities, DNA or proteins. It could also be about general and universal processes that could be implemented and realized in multiple forms. Moreover, while ALife was about biology at the beginning, its rationale and methods are now shared by many other domains, including chemistry, engineering, and the social sciences. In other words, the power to envision and synthesize "what is possible" beyond "what is" has transcended disciplinary boundaries. It also produces the material for the exploration of narratives about how things can be in principle and not only about their current state of being.

Artificial life has been able to touch other areas of study besides biology for at least two reasons: (1) It directly deals with the creation, analysis, and control of complex systems, and (2) there is wide recognition that the world is complex. It is not only that the world is naturally complex, but that the

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most pressing and challenging problems we humans face are entangled, with multiple dependences that simultaneously happen at many scales of complexity. Sustainability science, for example, has the notion of *wicked problems*. According to Conklin [2], these are problems that are characterized by not having a definitive formulation because they depend on who is framing them; such framings may depend on the interests and perceptions of a variety of stakeholders, they don't have a stopping rule, and their solutions are context-dependent and adaptive. Solutions to wicked problems are "one-shot operations," and a great amount of creative power is needed to come up with innovative solutions that might be beyond the scope of the initial space of solutions. In our experience, ALife's ability to bring forth adaptive and robust solutions to dynamic and complex situations is especially well suited to tackling wicked problems.

That ability to work with complex social phenomena comes from its very inception. Since then ALife has been open to a diversity of topics, including social, linguistic, and cultural issues, which are not limited to human behavior. A quick review of the ALife and ECAL conference proceedings of the last decade shows some patterns in the exploration of social phenomena from the perspective of artificial life [3]. Evolution of cooperation and social learning have been two of the most prominent topics, but the contributions of ALife to the understanding of social phenomena cannot be reduced only to those. The evolution of institutions has been an important topic, as well as reflection on new social dynamics emerging from new information and communication technologies. Biotechnology and the Web have also sparked interest as ways of creating natural-artificial hybrid entities, leading to the notion of living technology [4]. From a more encompassing perspective, the work done around these topics has contributed to a deeper and more theoretically grounded approach to subjects like cognition, language, individuality and autonomy, and evolution and evolvability, among others. All of these subjects have a common ground in the ALife research enterprise.

The Artificial Life Conference 2016 was dedicated to the special theme of ALife and Society [5]. The guiding question for the conference was *How can the synthetic study of living systems contribute to societies: scientifically, technically, and culturally?* No doubt, ALife has contributed to society as a scientific research enterprise by improving our understanding of complex systems. However, less has been done in societal outreach. ALife practitioners' expertise in complex systems and modeling can be of great use to tackle some of the most pressing problems that society is facing today. The problem space is wide: It spans from climate change to conflict and terrorism. Nonetheless, this may be the easiest and most obvious way to connect ALife research to society. Less obvious approaches to society are ethical analyses of the societal impact of new lifelike entities that are emerging from technology in relation to living things [6]. There is also a great area of opportunity for connecting ALife and education. Finally, ALife modeling might have an important role in social engagement. There are models that shouldn't aim for precision or accuracy but to kindle new pathways of social thought, and to create stories and narratives that we people can understand and to which we can relate [6]. This is a potential area of contribution for ALife in helping to deal with wicked problems. Decision makers, stakeholders, and the public in general need to understand the complexity of problems, but also they need to see the spectrum of possible trajectories of action. True, not all trajectories are viable or desirable, but that is exactly where ALife plays a special role. It can help to model, evolve, and visualize alternative trajectories that will help to escape from the limiting burdens of being trapped in a situation—being trapped in things-as-we-know-them, as opposed to being freed by exploring things-as-they-could-be. In this way artificial life research can play a useful role in helping us to think differently, serving as a method for realizing synthetic thought experiments [7].

This special issue includes four articles and three reports from the Artificial Life Conference 2016 that was held July 4–8 in Cancún, Mexico. Among others, this conference was special for two reasons. One of them is that it was the first time the conference took place in Latin America. It was fitting that this encounter took place in the Mayan Riviera, because the Maya had already long ago recognized the utility of artificially created living systems in their mythologies [8]. The other reason is that, for the first time, the conference included a special session on ALife outreach to society. We received 174 submissions, from which 68 were accepted as oral presentations, 41 as posters, and 21 as late-breaking abstracts that were also presented as posters. The works presented in this special issue were selected from among the 130 total accepted submissions to the conference due to their highest-scored reviews. We also chose these works because of their quality and because we believe their particular topics are of current interest for the community. Moreover, due to the Conference's special theme, there is a slight bias towards social topics.

Alexandra Penn reports about the special session *ALife and Society,* introducing a wide variety of topics, some of them not part of the main discussions among the ALife community but relevant in finding a connection with societal, ethical, and educational issues and problems. We can read in this report about the work of researchers who collaborate with indigenous people from the rural south of Mexico in an effort to bring together and improve the understanding of agroecosystems from the perspective of complex systems, about deep reflections about the limits of individuality in the context of the Internet of Things, and about the ethical aspects of lifelike technologies [6]. Noteworthy in this context is also that the *Artificial Life* journal has inaugurated a new section titled *Societal Impact of Artificial Life* [9].

In the same line of social interests but more on the research side than on that of outreach, there is a report on the *Social Learning and Cultural Evolution in ALife* workshop. Chris Marriott et al. present the different topics that revolve around the mechanisms of social learning and of those that may be responsible for cultural change. Moreover, a set of core questions and problems are identified [10]. Finally, concerning social themes, Simon T. Powers's article "The Institutional Approach for Modeling the Evolution of Human Societies" introduces a model on how rules can emerge as institutions among societies in a similar vein to that of Elinor Ostrom's thinking. This work is particularly relevant given that there is a need in the social sciences to develop more formal approaches to the evolution of institutions [11].

Inman Harvey's article moves to social and ecosystems levels of organization [12]. In his article the main issue is the relevance of history and its relationship with the robustness of dynamical systems towards internal perturbations that emerge from the tension between individual and collective interests. The models explored in the article reveal that there is an interesting articulation of contingency and robustness that has an analytical application to a wide array of dynamical systems.

Cognition and enactivism have long been a subject of importance for the ALife community. Eran Agmon and colleagues report on the *Biological Foundations of Enactivism* workshop, describing the interest of the participants in the importance of looking on the actual and future contributions of the enactivist perspective in understanding biology, the origins of life, and the emergence of autonomous systems and individuality from complex environments [13].

Santiago Hernández-Orozco and co-authors propose a rigorous theoretical framework linking computational undecidability and open-ended evolution. In their article "Undecidability and Irreducibility Conditions for Open-Ended Evolution and Emergence," the authors show that decidability sets the absolute limits to the growth of complexity in computational dynamical systems, which logically leads to a profound conclusion that open-ended evolutionary systems must be undecidable [14].

Finally, in "Multi-armed Droplets as Shape Changing Protocells," Jitka Čejková, Martin M. Hanczyc, and František Štěpánek explain that protocells can be implemented as droplets, vesicles, or solid particles, and as such, they can mimic some cell functions. Specifically, the authors focus their study on decanol droplets and their capacity to change shape which, under certain conditions, as explained in the article, these can develop appendages similar to those of bacteria or axons in neuronal cells. This work is interesting as artificial chemistry, for the study of artificial cells and their possible future technological applications [15].

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