



Anarchy and complexity



Carlos Maldonado

Universidad del Rosario, COL

Carlos Eduardo Maldonado has a Ph.D. in Philosophy from KULEuven (Belgium). He has been visiting professor and visiting research scholar at the University of Pittsburgh, the Catholic University of America (Washington, D.C.), and the University of Cambridge. He holds an honorary doctorate from the University of Timisoara (Romania). He is currently Research Professor at the School of Political Science and International Relations at Universidad del Rosario (Bogotá, Colombia).

Nathalie Mezza-Garcia

University of Warwick, ENG

Nathalie Mezza-Garcia is a PhD student at the Centre for Interdisciplinary Methodologies at the University of Warwick and a Rodolfo Llinás, Fundación CEIBA, Doctoral Fellow. She is interested in complexity science and her research studies how can internet-based technologies guide the self-organisation of human social systems and the biosphere. Her proposal is to have political systems with heterarchical topological networks, human decision-making based on interactive computation and automatic responses to real life data gathered with the Internet of Things. She is currently exploring open source legislation and how artificial intelligence and virtual worlds could help prevent crimes in the physical world.

This paper draws a philosophical parallel between the characteristics of anarchism with the sciences of complexity. The absence—*an*—of a ruling principle—*arche*, ἀρχή—is the *conditio sine qua non*, it is claimed, for a further search for ground and fundament. The most basic features common to both anarchism and complexity are the absence or critique to control as well as the importance of self-organization. Embracing the theory of complexity inevitably leads towards the acceptance of anarchy. A spirit of anarchy pervades complexity science even if: a) it has not been explicitly thematized, or b) it has not been the explicit concern of researchers and scholars working in the field.

Introduction

The future is undetermined, and as Bohr once pointed out, predicting is difficult especially when it is about future. Contemporary world is characterized by a constant fluctuation of events, and increasing uncertainty—in many levels and domains, systems and layers of reality. As it has been said, societies witness an increase in the degrees of freedom—which, by and large, is a positive feature—whilst *experiencing transitions away from hierarchical control*¹. This means that, increasingly, the world is becoming more and more unpredictable—at least by the means of the traditional models of classical science.

Nowadays, cutting-edge science is providing new mechanisms of explication for many types of social phenomena. The sciences of complexity are located within these sciences, and they are responsible for introducing more accurate and sophisticated models for understanding non-linearity and shed new lights on the understating and explanation of phenomena characterized by irreversibility, sudden changes, surprise, turbulence and fluctuations, for instance. To be sure, social interactions in human social systems are characterized by such features, particularly in the current non-zero sum world.

This paper argues that there is a strong conceptual and theoretical relationship between complexity and anarchism that has not been sufficiently seen and worked out in the literature about complexity. The claim is supported by four arguments, thus: firstly, complexity entails a scientific revolution, hence a radical shift in science. Such a scientific revolution can help manage complex human social systems. We do not dig into the rationale of the epistemology and history and philosophy of science but we focus on the implications of such a radical turn the complexity sciences entail. On this basis, the paper concentrates on the proper understanding of anarchism; this is the second section of the paper. Various explanations and levels are provided. Thirdly, the reasons supporting why complexity is, or leads to, anarchy are offered, that make clear the problematic stance of control when dealing with increasingly complex systems. Finally, the match is made the other way round as the paper shows why and how anarchy is seeded in complexity science, or also how the various features that characterize complexity can be taken up as features of anarchism. At end, several (open) conclusions are drawn.

Complexity as a scientific revolution: The language of complexity

By now, Kuhn's interpretation of the history of science in terms of scientific revolutions² is a common place. Kuhn was, as it has been pointed out, the right man in the right place. For, the understanding of science's march in terms of revolutions can be found in a number of authors more or less contemporary to Kuhn. Thus, ^{3,4,5}, and a bit later also ⁶ conceive of the history of science in terms of disruption, lack of continuity, breakdowns, and radical critique, rather than in linear terms and as linear progress. Further on, Serres goes up to interpreting the history of science as the story of bifurcations—exactly in the sense as the concept is understood in the framework of complexity theory. Here, for the sake of brevity, we shall take for granted the entire discussion and justification of scientific revolutions. We just take them up in terms of their consequences and entailments for complexity science.

The sciences of complexity, openly or tacitly, are a scientific revolution^{7,8,9}—a new science¹⁰. The very concept *the sciences of complexity* was donned early on at the Santa Fe Institute by the scientists, researchers and theoreticians devoted on the field meaning a radical shift *vis-à-vis* classical reductionist linear science.

The language of complexity encompasses concepts, behaviors and phenomena whose properties are, among others, nonlinearity, bifurcations, fractality, far-from-equilibrium behaviors, chaos and strange attractors, percolation and failure cascades, scale-free networks, degrees of freedom. Table 1 summarizes the language of complexity:

Indeed, a scientific revolution entails new forms of (social and knowledge) organization, new approaches, new rods, the use of metaphors, neologisms, and re-definitions⁷. It has been repeatedly pointed out that complex systems imply a sort of cultural and counter-intuitive character⁷⁷ throughout which new concepts are coined out whilst others that prevailed so far become useless and unnecessary.

Now, nonlinear behaviors as well as many of the concepts mentioned in table 1 are naturally endowed in political phenomena. Thus, the behavior of political agents, the evolution of political phenomena, and the cascading of political revolutions, for instance, are highly unpredictable. Public corruption travels and pervades a political organization thanks to informal complex networks of ties among public servants. Likewise, political decisions once applied over social systems usually produce irreversible outcomes. But so are economic dynamics too, as well as environmental processes and changes, for example. Such behavior can be grasped in terms of complexity theory as percolation. Like this, many other examples^{78,79,80} that evidence the complexity of political phenomena can be mentioned. However, as our world became increasingly interconnected, only very recently such endowment begun to be evident¹.

A key concept in complexity theory is degrees of freedom. Originated within physics and mathematics⁸¹ it refers to a system or behavior that loses rigidity, gains articulations and movement, and acquires flexibility either spatially or temporally. When the concept is transposed into politics and the social sciences it becomes highly suggestive. Thus, the complexity of a system corresponds to the degrees of freedom it has or exhibits. Social human systems have a large number of degrees of freedom that, however, are constrained or restricted by institutions that operate with centralized control. The structure and dynamics of those institutions have been identified as a tree topology^{82,83}. Yet, a tree topology is quite different from complex networks — the structure of human social systems—precisely in the rigidity and low degrees of freedom it has. Such a structure encompasses links, clusters and hubs. Synchrony and bursting⁶⁴.

Concepts	Relevant references
Complex adaptive system	11,12
Far-from-equilibrium	13,14
Chaos	15,16,17,18
Edge of Chaos	19
Fractality	20,21
Scale-free networks	22,26,27
Small Worlds	28,29,22
Sudden changes and surprise	30,31,32
Catastrophes	33,34,35
Modeling and simulation	11,36,37,38,39,40,41,42,43
Percolation	44,45
Failure cascades	44
Non-Classical Logics	46,47,48
P vs NP problems	49
Nonlinearity	50,51
Bifurcations	52
Self-organization	13,53,54,55,56,57
Crisis	58,59,33,60
Randomness	61,62,63
Bursting	64,65
Adaptation	66,67
Emergence	68
Dissipative structures	13
Phase transition	52
Swarm intelligence	69
Complex systems engineering	70,71,72
Cooperation	73,74,75,76
Turbulence	10

Table 1 *The language of complexity*

Politically, the history of mankind can be seen as the imposition of order in a top-down fashion upon human social systems. Thus, order and norms, control and verticality, centralization and discipline have traditionally been considered as compulsory for the existence of human systems. The use of laws, normativity, and symbolic group tags—most notably anthems, flags and national dates, etc.—do fulfill a restrictive role, or if one wishes, a unitary and coherent one. Institutions in general artificially restrict the natural tendency towards self-organization and self-control that human social systems would present in the absence of these coercive institutions⁸².

From a philosophical point of view, complexity can be seen as a sort of naturalization of the world and society. In general, over against physics that was the model or metaphor of modern science^{84,85}, biology and ecology have been taken as metaphors or models for highly complex systems. In this sense, according to Kauffman⁸⁶ the biosphere evolves as fast as it can, not faster or slower. This is very different from the way in which centralized institutions try to organize human social systems, by embracing the impossible task of regulating every possible human interaction, for instance via planning, strategies, goals, governmental or state policies, law, and the like. If so, the juridical laws and political normativity in their current form actually tend to block the harmonic evolution and adaptation of communities in the sociopolitical domain.

In contrast, complexity theory is teaching contemporary scientists that the best way to generate order in a complex system is by letting it self-organize in interaction with its environment. As a matter of fact, self-organization is a spontaneous behavior in complex systems, and the environment cannot be controlled. Self-organization, it appears, has been traditionally avoided in the history of social human systems, and diverse mechanisms have been developed to impede it. Thus, the idea of having leaders (in a strictly vertical sense) and governors dwindles in this scenario; top-down leaders become rulers, governors and commanders act as attractors that amplify negative feedbacks, as they inhibit the capacity of human social systems to generate their own adaptive order. Traditionally they have been called as “decision-makers”, along with CEOs at the corporate level. In many cases, the idea of the need of governors is the direct responsible for conflicts at mezzo and micro-levels (in-between cities and the globe). Indeed, micro social systems, provided with a defined political view, see formalized positions of power as the only way to reach their power objectives. As a consequence, the configuration of political systems reinforces the traditional idea of power. In the end, nation-states and corporations stand out against the own existence and well-being of humans and nature because inflate the maneuverability of a few groups upon the latter, which while aiming at increasing this capacity, limit the self-organization of human and natural social systems by imposing top-down control.

Being as it might be, the sciences of complexity provide sound models and explanations for understanding, deal and harness the nonlinearity of complex systems. Hereafter, we argue, politics could turn to the sciences of complexity as guidelines in times of increasing unpredictability of society.

Within the framework of complexity science the need for centralized control seems to be unfruitful, needless or highly limited⁸⁷. The same applies, a fortiori, for politics. Trying to achieve order in human social systems by turning to a centralized

authority brings, as it happens, more disruption. Imposed or external mechanisms of organization usually perturb the harmonic self-organization of socio-political dynamics⁸². In this context the current and mainstreamed justification of governments, modern states and leadership faces big challenges.

An important question arises then, namely how can political organization solve the problem of organizing increasingly complex social systems? We believe the substantial relationship that exists between anarchism and complexity can provide a solution to this problem. Embracing complexity as a scientific problem rather than as a theoretical framework inevitably leads to the plausibility of anarchic political organization. However, the relationship goes both ways: the sciences of complexity are *stricto sensu*, sciences of the anarchic, in the sense that they deal with non-governable systems. In the following, arguments will be provided.

Anarchy re-visited

The standard traditional understanding of anarchy links the concept with anonymity, disorder, lack of organization, and violence⁸⁸. Moreover, anarchism has been generally biased as or in a political context. The truth is that such an understanding falls short and does a little favor to the concept. Philosophically, anarchy does not imply disorder, but order⁸⁹—a specific type of order: a self-organized one that rises bottom-up⁹⁰. Following this, anarchism points to the idea of self-government^{91,92} and self-regulated systems without imposed or elected rulers⁹³. Consequently, anarchy could even lead to peaceful sociopolitical interactions; being an undetermined space for politics, it goes against the idea of imposition via centralized and top-down, i.e., usually coercive, mechanisms to achieve order.

There is a long history as to the concept and practice of anarchy and it encompasses a worldview wherein freedom, autonomy and independence are brought out openly to the fore. More specifically, over struggle and competition, the spirit of anarchy has always entailed cooperation, solidarity and the absence of self-interest, the rejection of authority whatsoever. Without going into a historical panorama, without any doubt, in the history of anarchy stand out the *akrasía* in the ancient Greece, the poetry of W. Blake, the noble spirit vis-à-vis the poorer by Kropotkin, the educational philosophy of H. Read, or the spiritual writings of the late Tolstoy, to mention but only some inspiring sources. Indeed, along history, anarchy has been expressed or also adopted by a number of authors. Thus, for instance,⁹⁴ Bakunin⁹⁵, Proudhon⁹⁶, Kropotkin^{97,98}, among many others have made of anarchist ideas their own way of thinking and living. From a methodological point of view, Feyerabend⁹⁹ has argued in favor of

a methodological anarchism. All in all, anarchy is not the opposite to organization, but only to hierarchy and power.

Anarchism has prevailed to some extent not only—and even not mainly, in politics, but also regarding the understanding of ecosystems, scientific method, economics, and art, among many fields. From a theoretical point of view, anarchy can be safely said as claiming for multiplicity, diversity, a criticism to monism in all its faces, and the absence of external constraints and restrictions. Now, such pluralism is one of the salient features of complexity, according to ¹⁰⁰. On the social scale, anarchy has always been matched with mutual-aid, cooperation, solidarity over against prevailing powers at every place and moment. Most notably, ¹⁰¹ have considered how cooperation is possible under anarchy. Furthermore, the complexity of cooperation—particularly in solving the Prisoner's Dilemma—has been worked out and to a large extent solved by ⁷⁴ on a simulated (agent-based) model.

Table 2 shows a general panorama of the fields and domains where anarchy has effectively existed so far.

Anarchy emerges as a concept and practice particularly in times and contexts of crisis, namely when steady order breaks down and turbulence and instability emerge; in other words, it appears when institutions and the establishment cannot cope with complexity. Nonetheless, it should be clearly pointed out that anarchy has nothing to do with messing up things—noise, arbitrariness. From a technical point of view, anarchy is about a radical critique to algorithmic systems and behaviors.

Economy	102,97,103,104
Art	105
Ecosystems and Nature	106,107
Politics	108,109,95,97,110,111,112,113,114
Philosophy	115
Poetry	116
Archaeology	117
Social Movements	118
Sexual Liberation	119
Religion	120
Anthropology	91
Education	121

Table 2 *Anarchist theories and fields*

There are three main ways of organization for structuring and organizing a society, namely hierarchies, heterarchies and anarchies. Hierarchies entail tree topologies, pyramidal, rigid, vertical, political regimes, centralized control and Turing-like decision-making processes. Hierarchies can easily be explained as linear, i.e., sequential structures and as law-like dynamics. By and large they are the predominant standard view of human history, particularly when seen from the standpoint of the western civilization. A critique to the topology and architecture of these pyramidal control systems has been considered by ⁸².

In contrast, in heterarchies power is distributed horizontally¹²². A conspicuous historical example of a heterarchical systems is the Incaic history in ancient Peru¹²³ or also the Tayronas, Muisca, and Sinú cultures in pre-Columbian history¹²⁴. Whereas hierarchies can be said to be uniform in history, heterarchies can differ greatly from one another, since they obey particular characteristics of the community where they exist. Paradoxically, heterarchies were present during most of the history of human societies, although they were not properly seen by the official history in the west. Ubiquitous throughout the world in indigenous societies, some even survive to-date^{125,126}. The western world has been possible at the cost of stealing other peoples and cultures history and tradition, as Goody¹²⁷ has argued.

As to anarchies, they have only existed at the level of local communities and as alternatives to the current *Zeitgeist* in a given period. From a theoretical point of view, anarchy, we claim, shares the spirit of complexity science, since the bottom-line is about gaining degrees of freedom. Indeed, a complex system has been defined as a system that: a) either has (a large) degrees of freedom, or b) gains degrees of freedom—so much so that the more degrees of freedom a system exhibits the more complex it is. From a social, economic, and political standpoint, the contrary becomes more than evident, namely if and when any given system loses degrees of freedom its complexity decreases. The crux here is that complexity science is about *increasingly* complex systems. To be sure, among all the possible political systems anarchy could be seen, or is, as the most complex.

The idea of control has been systematically and deeply grounded along the history of the western civilization. From this point of view, the claim for anarchy may sound counter-intuitive. Axelrod and Cohen have argued about the need and feasibility of *harnessing complexity*¹²⁸ which can be taken as understanding, working with, and living in and with complex phenomena, instead of just rejecting or manipulating them. On a different track, Taleb⁶⁰ argues in favor of anti-fragile systems and thinking, meaning the capacity to evolve and adapt, in other words change.

To be sure, there is no one only form of anarchism. Etymologically, its origins bases upon the assumption of the absence—*an* (άν), which means *no-* of a ruling principle—*arche* (άρχή). As such the concept was coined in the archaic Greece, i.e., before the transition to democracy and the outset of the western civilization in the classical Greece. In its vulgar or popular sense, anarchy has been traditionally taken as disorder, chaos, anomy, and lack of any kind of organization. Such an understanding is, however, mistaken.

Indeed, *an-archy* is the condition for a further search for principles and rules and it reveals, moreover, as the *conditio sine qua non* to any possible life and organization to be. In other words, it is the autonomy, the freedom, the independence that allows for higher or better horizons, dynamics and structures. Anarchy, it appears, is the very seed and proper name for freedom, autonomy and cooperation.

Mainstream political theories work as lenses through which every sociopolitical interaction is measured and standardized. These lenses advocate for a single, and moreover, a unique way for doing politics. Liberalism, most notably, implies that representative democracy is the best way to validate sociopolitical interactions, and that the latter should be subdued to a higher level structure called the rule of law. From a philosophical take, democracy seems to be the only reasonable way in the story of western civilization.

On the other side, in his critique to capitalism Marxism Bakunin proposed the dictatorship of the proletariat while holding the same tree topology of its counterpart because he was aware of how the ideal of the supremacy of the proletariat would still hold the existence of a closed group of people—sort of aristocracy¹¹⁰. The communist system as claimed by Marxists would seek and maintain more power and means, essentially preserving thus the traditional structure of a vertical and hierarchic society and history. The despotism of the closed unique party of the Bolsheviks on top of the Soviet Union and other countries for decades helped enhance this idea. Originally and paradoxically, the Bolsheviks emerged from self-organized assemblies of workers called the *soviets*. Despite the desire of the soviets of pursuing equality in society, it was Lenin and his party who centralized the authority and managed thus to manipulate and deviate a spirit that was essentially anarchic, i.e., self-organized ¹²⁹.

Since Bakunin's time, the situation has not changed dramatically—for most countries are still ruled by closed aristocracies—with a variety of names: corporatism, aristocracy, institutionalism and neo-institutionalism, etc. Nevertheless, such artificial way of trying to achieve order in human society contrasts with the complexity that characterizes its interactions and the organicity that is present in its dynamics.

Being as it might be, traditional political systems focus on control—top-down control, specifically—, on the idea of hierarchies and on pyramidal, rigid, vertical, closed and static structures and norms. A worldview with centered, hierarchical and rigid organization corresponds to the anthropocentric view of the universe. In such a worldview, nature is conceived and justified as a means for the needs and wants of mankind. The anthropocentric view of nature corresponds to the junction of Athens, Jerusalem, and Rome—the outset of the western civilization.

A vertical and pyramidal interpretation and organization of the world and nature was reinforced early on with the importance of algorithm, namely rules, norms and recipes for the world to be possible. Thus, law and the legal system came to play a fundamental role, all of which artificially blocks the natural tendency to self-organize that human social systems, as every other complex system, present in the absence of top-down and centralized control. Nature was entirely explained and managed as a law-like phenomenon. As such, law parameterizes and defines, constraints and limits while pretending to liberate and free.

Over against hierarchies, power and control, the idea of cooperation and self-organization can be adequately seen as the rationale of and for anarchy. Indeed, an anarchic, i.e., self-organized system is the one where networks and interaction play an up most fundamental role. Cooperation, thus, entails horizontality, parallelism, the absence of a rigid center. Kropotkin, reading up from Darwin, argued in favor of a networked society based upon mutual aid ⁹⁷. In other words, ethics and compassion, solidarity and friendship, trust and giving are to be seen as the ground for a truly humane society—instead of interest and self-interest, authority and profit, competition and predation, for instance.

A remark here is necessary. Various anarchic movements can be seen in history, from religious (Cathars) to political (Russia, Italy or Spain), from artistic (surrealism) to economic (self-managing movements) or philosophical (such as pantheism) and always as local experiences. In fact, when looking at historical anarchic organizations the relatively triumphant experiences of anarchic social movements pertain to a zero-sum world. Now, since we have come to live in a non-zero-sum world, the possible history of anarchism toward future entails far more complex considerations that remain out of the scope of this paper. Here we restrict ourselves, for reasons of space, to a conceptual level. Complexity science can be safely said to be the kind of science in and for a non-zero sum world.

Why complexity is anarchic

The sciences of complexity are sciences of the anarchic in the sense it has been argued above. There is, as it happens, no one definition for complexity¹³⁰; for a reply to Horgan's article, see M. Mitchell's <http://tuvalu.santafe.edu/~jpc/SciAm-Public.html>). Increasingly complex systems have been said to be non-linear⁵¹, adaptive⁶⁶, open, far-from-equilibrium¹³ or on the edge of chaos¹³¹, synthesized bottom-up⁶⁸ non-algorithmic^{132,133}—among many other features or properties.

The sciences of complexity are made up by a number of sciences (such as chaos¹⁵, non-equilibrium thermodynamics¹⁴, complex networks²⁸), a number of theories (catastrophe theory³³, self-organization⁵⁷, turbulence¹⁰), approaches (first and second phase transition order¹³⁴, swarm intelligence¹³⁵), methods (modeling and simulation^{40,74}, metaheuristics⁴³), concepts (percolation⁴⁴, failure cascades⁴⁴, adaptation⁶⁶ and learning), problems (P versus NP problems¹³⁶, optimization¹³⁷, crises⁵⁹, randomization⁶¹)—to name but a few.

There is no such a thing as a superior approach for understanding complex systems, phenomena or behaviors, very much as there is not supremacy of method, either. One of the great merits of complex theory has been showing and proving that there are only open systems—for closed or isolated systems are either abstractions or experimental or theoretical restraints.

From a negative standpoint, there is no one single method, language, approach, discipline, rod, or even science that defines the entire set of the sciences of complexity. Moreover, there is no a unique answer to questions such as: what is a complex system? Or, how does a system become complex? A correct understanding of increasingly complex systems is rather reluctant to classical approaches that are deterministic and reductionist. Notoriously, in the framework of complexity science parameterization, linearization, isolation of systems and phenomena, for example, become not only unfruitful but artificial and unnecessary. In contrast, a salient feature of complexity can be taken to be multiplicity and plurality, diversity and alterity. If complexity sciences have been said to be cross-disciplinary or interdisciplinary, they are then characterized by a manifold of theories, concepts, tools, rods, and approaches.

To be sure, complexity theory entails a philosophy of movement. However, unlike modern science in general, complexity science does not focus on regular, periodic, cyclic movement. Such is, indeed, the concern of classical mechanics, which identifies and explains regular movements in terms of law-like phenomena, and as pendulum oscillations. In fact, the concept used from Galileo to Newton to express such kind of

movement is “revolution”, namely “orbits”, “periods”. In contrast, complexity science focuses on sudden, unpredictable, irregular, aperiodic, irreversible movement. It is exactly this type of movement that is explained by the concepts and rods mentioned above.

Classical science is science of control and prediction, the prevalence of causality, determinism and reductionism^{32,138}, and normal distributions. In contrast, the sciences of complexity concentrate on power laws, emergence, surprise, order through fluctuation, among others. The concept of degrees of freedom is central to the understanding of complex phenomena. Modeling and simulation allow working with counter-intuitive relations, bursting and networks, and the Hilbert space is useful in this context. More radically, complex systems are non-algorithmic^{139,140}. The political consequences of complexity science have been highlighted by¹⁴¹.

We would like to suggest that complexity science is not just about explaining and understanding non-linear, self-organized and emergent phenomena and systems. Additionally, it is additionally about complexifying systems, behaviors and phenomena.

Let us focus on the concept of degrees of freedom. Anarchist thinkers in general have argued in favor of a complexification of phenomena exactly in terms of increasing degrees of freedom, even though many of them may have not used the technical expression. A spirit of anarchy pervades complexity science even if: a) it has not been explicitly thematized, or b) it has not been the explicit concern of researchers and scholars working in the field. A system or behavior that gains degrees of freedom is said to be of increasing complexity, and nonlinearity serves as an adequate expression, for we are forced to work with the n solutions the system has, simultaneously, i.e., without maximizing, choosing, or selecting a particular solution from the set available in and by the system.

We would like to stress this point: complexity theory is about both understanding and explaining phenomena whose behavior entails gaining degrees of freedom, and striving to enhance or produce (harness) increasing complexity in the world. Thus, sooner than later the concept that emerges along with degrees of freedom is randomness. According to Kolmogorov⁶¹ and Chaitin⁶² a complex system is ultimately a random one.

Besides, one of the key concepts in complexity science is bifurcation. A bifurcation is the change of the history of a given phenomenon, or also a qualitative change of a system. Bifurcations take place via two main roads, so to speak, thus: as first order phase transition or second order phase transition¹³⁴. Hence after, bifurcations go hand

in hand with non-linearity and, as a consequence, the system under consideration gains degrees of freedom. Such a process can be literally said as the very process through which the system liberates from control and rigidity.

In other words, as complex systems increase their degrees of freedom via bifurcations, they are pushed to the edge of chaos and become less feasible to be controlled. In the study of living beings, it has been argued that evolution^{54,142,143} leads the systems—from the cell to the biosphere—to the edge of chaos. Thus, complexity sciences study systems, phenomena and behaviors of anarchic nature. Organization, structure and dynamics that are the result of self-organized interactions do not follow any teleological end. It is important to recall that anarchy does not imply a lack or absence of organization, at all. Anarchy is that kind of organization: a) that emerges bottom-up and is linked and supported by local interactions; b) that both allows and is the outcome of increasing degrees of freedom.

There is, as it happens, a positive feedback loop between self-organization and anarchy. Now, vis-à-vis a controlled movement, emergence and self-organization could be taken, particularly in the framework of human society as (symptoms of) crises or as a disruption. Pyramidal powers have since ever feared emergence, self-organization, increasing degrees of freedom, sudden and unpredictable change. We strongly suggest that systems science and not complexity sciences are much more suitable to established powers and control.

How complexity pervades anarchy

Along the way as there is not one single definition of anarchy, in the same tenure, there is no a unique definition for complexity. Complexity just like anarchy lacks any—singular or fundamental—ruling principle. Notwithstanding, both, anarchy and complexity share almost the same guidelines, so much so that it is plausible to state that complexity, as a scientific problem, and the sciences of complexity that deal with it, are sciences of the anarchic, i.e., of those systems characterized by increasing degrees of freedom, self-organized and even in self-organized criticality, non-algorithmic.

Several authors have argued in favor of understanding complexity science vis-à-vis the most complex systems known to-date, life, i.e., living beings. Thus, besides gaining degrees of freedom, complexity is about life. According to¹⁴⁴, in a political context, life can only become possible in social spaces that allow far-from-equilibrium

interactions among individuals, which can only take place beyond the constraints of institutions, and far from a Newtonian-based language in politics focused on the concepts of force, power and law, mass, action-reaction, for instance. In other words, an increasingly complexifying world can only evolve in harmony if its environment admits increases in degrees of freedom—evolution, adaptation and learning. Table 3 evidences the later features in anarchy and contrasts them with traditional political systems.

Attributes	Anarchy	(Centralized) Political Systems
Order by means of	Self-Organization	Imposed Normativity
Information Processing	Bottom-Up Interactive Decentralized	Top-Down Algorithmic-like A central (unit) processor
Topology Distribution of power Composition of the networks	Complex networks Nested heterarchies Heterogeneous	Tree topology Hierarchical Homogenized
Evolution via Structure Nature of crisis	Adaptation and learning Antifragile Unpredictable	Reforms Robust/Fragile Predictable
Outcomes of crisis Tools for decision-making processes Future dynamics	Learning Local consensus, metaheuristics, modeling and simulation Autonomy, freedom, autarchy	Dwindling Deliberation processes in closed and isolated political regimes Control and manipulation
Relation with Nature	Harmonic	Exploitation, Predatory

Table 3 *Attributes of political systems*

Correspondingly, anarchic political organizations are highly complex arrangements. Complexity science and anarchism share a common salient feature, namely naturalization of the world and of epistemology. Nature, it has been said, works in parallel, and does not put all eggs in one and the same basket—and plays (kicks off) with the basket. Naturalizing society, i.e., the social organization of human beings is a claim that either nurtures from anthropology and history, or also from biology, ecology and evolution theory. It can be said that nature's topology is a flexible and adaptive one, essentially open and ever-learning.

Because anarchic political organizations arise from local, i.e., self-organized, interactions, groups of individuals in anarchism would probably follow preferential attachment formation processes. The resulting political structure in anarchism would thus become a complex network⁸² in the sense precisely as complex networks have been studied and characterized in the literature.

Since imposed order is opposite to anarchism, anarchies are propitious for self-organization and diversity to flourish. It is generally thought that centralized control and vertical structures are necessary to rule human societies. However, there are many successful examples¹⁰⁴ of self-organization and non-centralized dynamics as the best way to organize complex systems. Life in general, a self-organized phenomenon, is probably the best example.

There is indeed a strong correlation between self-organization and surprise¹⁴⁵. Self-organized behaviors or phenomena result in emergent properties that cannot be directly traced back to the sum of the properties or systems from where they emerged. Self-organized systems are incredible innovating, as they are constantly adapting to fluctuations in the environment and within them. Most of time, such fluctuations are unpredictable, whence self-organization becomes the best way to deal with surprises.

Reasonably, human social systems can share the same topology, i.e., architecture as nature. Harnessing complexity and complexifying phenomena provide a further rationale for and around complex systems. Anarchy would indeed be feasible to be described with properties of complex systems, such as openness, learning, evolution, adaptation, self-organization, among others. Anarchic systems of decisions would be self-organized, decisions would be synthesized bottom-up, and information processing would be interactive.

Concluding remarks

We have argued in favor of anarchy and claimed that the sciences of complexity share a common wave-length, so to speak, with an *an-archic* spirit. Anarchy entails cooperation and solidarity over against violent powers and has been historically a response or space for freedom, autonomy and independence, rooting in or emerging from self-organization. It can be safely said that the history of hierarchical systems corresponds with, and is a cause of, violence in human history. The basic reason is that generally they only know and care about themselves. One aspect for embracing the sciences of complexity when theorizing about political organization is that complexity science allows highlighting harmony as stated by¹⁴⁶. A tacit till-now relationship between anarchy and complexity theory can hereafter become an explicit issue for the community of complexologists. The issue encompasses the human scale and the understanding of nature, as well as epistemological assumptions that have not been explicitly thematized, so far.

References

1. Bar-Yam, Y. (1997). *Dynamics of Complex Systems*, [ISBN 9780201557480](#).
2. Kuhn, T. (2012). *The Structure of Scientific Revolutions*, [ISBN 9780226458120](#).
3. Hall, A.R., and Dunstan, G. (1954). *The Scientific Revolution, 1500-1800: The Formation of the Modern Scientific Attitude*, [ISBN 9780226750217](#).
4. Cohen, I.B. (1985). *Revolution in Science*, [ISBN 9780674767775](#).
5. Cohen, I.B. (1964). "History and philosophy of science," *Proceedings of the American Catholic Philosophical Association*, [ISSN 0065-7638](#), 38: 36-46.
6. Serres, M. (1991). *Historia De Las Ciencias*, [ISBN 9788437609881](#).
7. Cowan, G., Pines, D., and Meltzer, D. (1999). *Complexity: Metaphors, Models, and Reality*, [ISBN 9780201626063](#).
8. GellMann, M. (1995). *The Quark and the Jaguar: Adventures in the Simple and the Complex*, [ISBN 9780716725817](#).
9. Maldonado, C.E. (2009). *Complejidad: Revolución Científica y Teoría*, [ISBN 9789587380309](#).
10. Wolfram, S. (2002). *A New Kind of Science*, [ISBN 9781579550080](#).
11. Miller, J., H., and Page, S. (2007). *Complex Adaptive Systems: An Introduction to Computational Models of Social Life*, [ISBN 9780691127026](#).
12. Holland, J. (1962). "Outline for a logical theory of adaptive systems," *Journal of the ACM*, [ISSN 0004-5411](#), 3: 279-314.
13. Nicolis, G., and Prigogine, I. (1977). *Self-Organization in Nonequilibrium Systems*, [ISBN 9780471024019](#).
14. Prigogine, I. (1961). *Introduction to Thermodynamics of Irreversible Processes*, [ISBN 9780470699287](#).
15. Lorenz, E. (1963). "Deterministic non-periodic flow," *Journal of the Atmospheric Sciences*, [ISSN 0022-4928](#), 20: 130-141.
16. Gribbin, J. (2009). *Deep Simplicity: Chaos, Complexity and the Emergence of Life*, [ISBN 9780141007229](#).
17. Prigogine, I., and Stengers, I. (1984). *Order Out of Chaos*, [ISBN 9780434603954](#).
18. Badii, R., and Politi, A. (1985). "Statistical description of chaotic attractors: The dimension function," *Journal of Statistical Physics*, [ISSN 0022-4715](#), 40: 725-750.
19. Lewin, R. (2000). *Complexity: Life at the Edge of Chaos*, [ISBN 9780025704855](#).
20. Mandelbrot, B.B. (1983). *The Fractal Geometry of Nature*, [ISBN 9780716711865](#).
21. Mandelbrot, B.B. (1977). *Fractals*, [ISBN 9780716704737](#).
22. Watts, D.J. (2003). *Six Degrees: The Science of a Connected Age*, [ISBN 9780393325423](#).
23. Barabasi, A.L. (2003). *Linked: How Everything Is Connected to Everything Else and What It Means for Life, Science and Everyday Life*, [ISBN 9780465085736](#).

24. Solé, R. (2009). *Redes Complejas: Del Genoma a Internet*, [ISBN 9788483831175](#).
25. Estrada, E. (2012). *The Structure of Complex Networks, Theory and Applications*, [ISBN 9780199591756](#).
26. Watts, D. (2004). "The 'New' Science of Networks," *Annual Review of Sociology*, [ISSN 0360-0572](#), 30: 243-270.
27. Strogatz, S. (2003). *Sync: How Order Emerges from Chaos in the Universe, Nature, and Daily Life*, [ISBN 9780786887217](#).
28. Strogatz, S., and Watts, D. (1998). "Collective dynamics of 'Small World' Networks," *Nature*, [ISSN 0028-0836](#), 393: 440-442.
29. Travers, J., and Milgram, S. (1969). "An experimental study of the small world problem," *Sociometry*, [ISSN 0038-0431](#), 32: 435-442.
30. Eldredge, N., and Gould, S.J. (1972). "Punctuated equilibria: An alternative to phyletic gradualism," in T.J.M Schopf (ed.), *Models in Paleobiology*, [ISBN 9780877353256](#), pp. 82-115
31. Maldonado, C.E. (2005). "Ciencias de la complejidad: ciencias de los cambios súbitos," *Odeon Observatorio de Economía y Operaciones Numéricas*, ISSN 1794-1113, 85-125.
32. Casti, J. (1994). *Explaining a Paradoxical World through the Science of Surprise*, [ISBN 9780060925871](#).
33. Thom, R. (1976). "Crise et catastrophe," *Communications*, [ISSN 0588-8018](#), 25:1.
34. Maldonado, C.E. (2006). "Teoría de catástrofes y teoría financiera," *Odeon Observatorio de Economía y Operaciones Numéricas*, ISSN 1794-1113, 47-74.
35. Zeeman, E.C. (1979). *Catastrophe Theory*, [ISBN 9780201090147](#).
36. Von Newman, J. (1994). "Theory of self-reproducing automata," *IEEE Transactions on Neural Networks*, [ISSN 1045-9227](#), 5: 3-14.
37. Wolfram, S. (1984). "Universality and complexity in cellular automata," *Physica D: Nonlinear Phenomena*, [ISSN 0167-2789](#), 10: 1-35.
38. Langton, C. (1986). "Studying artificial life with cellular automata," *Physica D: Nonlinear Phenomena*, [ISSN 0167-2789](#), 22: 120-149.
39. Michalewicz, Z., Schmidt, M., Michalewicz, M., and Chiriac, C. (2007). *Adaptive Business Intelligence*, [ISBN 9783540329282](#).
40. North, M., and Macal, C. (2007). *Managing Business Complexity: Discovering Strategic Solutions with Agent-Based Modeling and Simulation*, [ISBN 9780195172119](#).
41. Resnick, M. (1997). *Turtles, Termites and Traffic Jams*, [ISBN 9780262181624](#).
42. Floreano, D., and Mattiussi, C. (2008). *Bio-Inspired Artificial Intelligence: Theories, Methods and Technologies*, [ISBN 9780262062718](#).
43. Talbi, E.G. (2009). *Metaheuristics: From Design to Implementation*, [ISBN 9780470278581](#).
44. Bak, P., Tang, C., and Wiesenfeld, K. (1988). "Self-organized criticality," *Physical Review*, [ISSN 0031-899X](#), 38: 364-374.

45. Bonabeau, E. (2002). "Agent-based modeling: methods and techniques for simulating human systems," *Proceedings of the National Academy of Sciences*, [ISSN 0369-8203](#), 7280-7287.
46. Palau, G. (2002). *Introducción Filosófica a Las Lógicas No-Clásicas*, [ISBN 9788474320022](#).
47. Maldonado, C.E. (2007). "Lógicas no-clásicas (5): la lógica cuántica," *Zero*, ISSN 0123-8779, 164-168.
48. Maldonado, C.E. (2006). "Lógicas paraconsistentes," *Zero*, ISSN 0123-8779, Diecisiete: 142-152.
49. Fortrow, L. (2009). *The Golden Ticket: P, NP, and the Search for the Impossible*, [ISBN 9780691156491](#).
50. Scott, A.C. (2007). *The Nonlinear Universe: Chaos, Emergence, Life*, [ISBN 9781402062698](#).
51. Nicolis, G., and Nicolis, C. (2007). *Foundations of Complex Systems: Nonlinear Dynamics, Statistical Physics, Information and Prediction*, [ISBN 9789812700438](#).
52. Solé, R.V. (2011). *Phase Transitions*, [ISBN 9780691150758](#).
53. Kauffman, S.A. (1993). *The Origins of Order: Self-Organization and Selection in Evolution*, [ISBN 9780195058116](#).
54. Kauffman, S.A. (1995). *At Home in the Universe: The Search for the Laws of Self-Organization and Complexity*, [ISBN 9780195111309](#).
55. Kauffman, S.A. (2000). *Investigations*, [ISBN 9780195121056](#).
56. Turing, A. (1952). "The chemical basis of morphogenesis," *Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences*, [ISSN 0080-4622](#), 237: 37-72.
57. Camazine, S., Deneubourg, J.I., Franks, N., Sneyd, J., Theraulaz, G., and Bonabeau, E. (2002). *Self-Organization in Biological Systems*, [ISBN 9780691116242](#).
58. Gilpin, D.R. (2008). *Crisis Management in a Complex World*, [ISBN 9780195328721](#).
59. Taleb, N.N. (2010). *The Black Swan: The Impact of the Highly Improbable Fragility*, [ISBN 9780812973815](#).
60. Taleb, N.N. (2012). *Antifragile: Things That Gain from Disorder*, [ISBN 9780812979688](#).
61. Kolmogorov, A.N., and Uspenskii, V.A. (1987). "Algorithms and randomness," *Theory of Probability and its Applications*, [ISSN 0040-585X](#), 32: 389-412.
62. Chaitin, G.J. (1990). *Information, Randomness and Incompleteness: Papers On Algorithmic Information Theory*, [ISBN 9789810201548](#).
63. Chaitin, G.J. (1975). "Randomness and mathematical proof," *Scientific American*, [ISSN 0036-8733](#), 232: 47-52.
64. Barabasi, A.L. (2011). *Bursts: The Hidden Patterns Behind Everything We Do, from Your E-Mail to Bloody Crusades*, [ISBN 9780452297180](#).
65. Barabasi, A.L. (2005). "The origin of bursts and heavy tails in human dynamics," *Nature*, [ISSN 0028-0836](#), 435: 207-211.
66. Holland, J.H. (1996). *Hidden Order: How Adaptation Builds Complexity*, [ISBN 9780201442304](#).

67. Holland, J.H. (1992). *Adaptation in Natural and Artificial Systems*, [ISBN 9780262581110](#).
68. Holland, J.H. (1998). *Emergence: From Chaos to Order*, [ISBN 9780201149432](#).
69. Dorigo, M., and Birattari, M. (2007). "Swarm intelligence," *Scholarpedia*, ISSN 1941-6016, 2: 1462.
70. Banzhaf, W., and Pillay, N. (2007). "Why complex systems engineering needs biological development," *Complexity*, [ISSN 1076-2787](#), 13: 12-21.
71. Braha, D., Minai, A.B.Y., and Yanner. (2006). *Complex Engineered Systems*, [ISBN 9783540328315](#).
72. Maldonado, C.E., and Gómez Cruz, N.A. (2012). "The complexification of engineering," *Complexity*, [ISSN 1076-2787](#), 17: 8-15.
73. Axelrod, R. (2006). *The Evolution of Cooperation*, [ISBN 9780465005642](#).
74. Axelrod, R. (1997). *The Complexity of Cooperation*, [ISBN 9780691015675](#).
75. Santos, F., and Pacheco, J.M. (2005). "Scale-free networks provide a unifying framework for the emergence of cooperation," *Physical Review Letters*, [ISSN 0031-9007](#), 95: 098104.
76. Santos, F., Santos, M.D., and Pacheco, J.M. (2008). "Social diversity promotes the emergence of cooperation in public goods games," *Nature*, [ISSN 0028-0836](#), 454: 213-216.
77. McCabe, V. (2014). *Coming to Our Senses: Perceiving Complexity to Avoid Catastrophes*, [ISBN 9780199988587](#).
78. Harrison, N.E. (2007). *Complexity in World Politics: Concepts and Methods of a New Paradigm*, [ISBN 9780791468081](#).
79. Rosenau, J.N. (1990). *Turbulence in World Politics: A Theory of Change and Continuity*, [ISBN 9780691023083](#).
80. Richards, D.E.-A. (2000). *Political Complexity: Nonlinear Models of Politics*, [ISBN 9780472109647](#).
81. Badii, R., and Politi, A. (1999). *Complexity: Hierarchical Structures and Scaling in Physics*, [ISBN 9780521418904](#).
82. Mezza-Garcia, N., and Maldonado, C.E. (2014). "Crítica al control jerárquico de los regímenes políticos clásicos: complejidad y topología," *Desafíos*, [ISSN 0124-4035](#), in press.
83. Mezza-Garcia, N. (2012). "Bio-inspired political systems: opening a field," in T. Gilbert (ed.), *Proceedings of the European Conference on Complex Systems*, [ISBN 9783319003948](#), pp. 758-812.
84. Ball, P. (2004). *Critical Mass, How One Thing Leads to Another*, [ISBN 9780374530419](#).
85. Mainzer, K. (2007). *Thinking in Complexity: The Computational Dynamics of Matter, Mind and Mankind*, [ISBN 9783540722274](#).
86. Kauffman, S.A. (2002). *Investigations*, [ISBN 9780195121056](#).
87. Schuster, P. (2004). "The disaster of central control," *Complexity*, [ISSN 1076-2787](#), 9: 13-14.

88. Munch, P. (1974). "Anarchy and anomie in an anarchist community," *Man*, [ISSN 0025-1496](#), 9: 243-261.
89. Koziatkiewicz, J., and Kostera, M. (1998). "Creativity out of chaos," *Human Resource Development International*, [ISSN 1367-8868](#), 1: 383-398.
90. Guérin, D. (1970). *Anarchism: From Theory to Practice*, [ISBN 9780853451754](#).
91. Barclay, H. (1996). *People Without Government: An Anthropology of Anarchy*, [ISBN 9781871082166](#).
92. Wachhaus, A. (2011). "Anarchy as a model for network governance," *Public Administration Review*, [ISSN 0033-3352](#), 72: 33-42.
93. Woodcock, G. (1962). *Anarchism: A History of Libertarian Ideas and Movements*, [ISBN 9781258115272](#).
94. Mandeville, B.D. (1989). *The Fable of the Bees: Or, Private Vices, Public Benefit*, [ISBN 9780872203747](#).
95. Bakunin, M. (1999). *Bakunin: Statism and Anarchy*, [ISBN 9780521369732](#).
96. Proudhon, P.J. (1876). *What Is Property? An Inquiry into the Principle of Right and Government*, [ISBN 9781508623748](#).
97. Kropotkin, P. (2012). *Mutual Aid: A Factor of Evolution*, [ISBN 9781497333734](#).
98. Bookchin, M. (1984). *Visions of Utopia*, [ISBN 9780917352140](#).
99. Feyerabend, P.K. (1993). *Against Method*, [ISBN 9781844674428](#).
100. Mitchel, S.D. (2003). *Biological Complexity and Integrative Pluralism*, [ISBN 9780521520799](#).
101. Axelrod, R., and Keohane, R.O. (1985). "Achieving cooperation under anarchy: strategies and institutions," *World Politics*, [ISSN 0043-8871](#), 38: 226-254.
102. Hayek, F. (1978). *Law, Legislation and Liberty*, [ISBN 9780226320861](#).
103. Kropotkin, P. (1990). *The Conquest of Bread*, [ISBN 9780141396118](#).
104. Mintz, F. (1976). *L'Autogestion Dans L'Espagne Révolutionnaire*, [ISBN 9782707108739](#).
105. Banský. (2006). *Wall and Piece*, [ISBN 9781844137879](#).
106. Bookchin, M. (1982). *The Ecology of Freedom: The Emergence and Dissolution of Hierarchy*, [ISBN 9781904859260](#).
107. Purchase, G. (1997). *Anarchism and Ecology*, [ISBN 9781551640266](#).
108. Guérin, D. (1970). *Anarchism: From Theory to Practice*, [ISBN 9780853451754](#).
109. Proudhon, P.J. (1876). *What Is Property? An Inquiry into the Principle of Right and Government*, [ISBN 9781508623748](#).
110. Bakunin, M. (2012). *Selected Writings from Mikhail Bakunin: Essays On Anarchism*, [ISBN 9781934941836](#).
111. Chomsky, N. (2005). *Chomsky on Anarchism*, [ISBN 9781904859208](#).
112. Kropotkin, P. (2012). *Anarchism: A Collection of Revolutionary Writings*, [ISBN 9780486419558](#).

113. Thoreau, H.D. (2012). *Civil Disobedience and Other Essays*, [ISBN 9780486275635](#).
114. Tolstoy, L. (1990). *Government Is Violence: Essays On Anarchism and Pacifism*, [ISBN 9780948984150](#).
115. Kropotkin, P. (2012). *Anarchist Morality*, [ISBN 9780973782745](#).
116. Blake, W. (1975). *The Marriage of Heaven and Hell*, [ISBN 9781495923869](#).
117. Angelbeck, B., and Grier, C. (2012). "Anarchism and the archaeology of anarchic societies," *Current Anthropology*, [ISSN 0011-3204](#), 52: 547-587.
118. Boochkin, M., Liguri, D., and Srowasser, H. (2007). *La Utopía Es Posible*, [ISBN 9789509870017](#).
119. Baigorria, O.C. (2006). *Amor Libre: Eros Y Anarquía*, Terramar Ediciones, [ISBN 9788481365832](#).
120. Bakunin, M. (2012). *God and the State*, [ISBN 9780486224831](#).
121. Read, H.E. (1974). *Education through Art*, [ISBN 9780571055593](#).
122. Crumley, C.L. (1995). "Heterarchy and the analysis of complex societies," *Archeological Papers of the American Anthropological Association*, [ISSN 1551-823X](#), 6: 1-15.
123. Posnansky, A. (1945). "Tiwanaku: la cuna del hombre americano," <http://pueblosoriginarios.com/primeros/tiuanacu.html>.
124. Mezza-Garcia, N., Froese, T., and Fernández, N. (2014). "Reflections on the complexity of ancient social heterarchies: toward new models of social self-organization in pre-Hispanic Colombia," *Journal of Sociocybernetics*, [ISSN 1551-8248](#), 12: 3-17.
125. Giraldo Pélaez, S. (2009). *Parque Arqueológico Teyuna-Ciudad Perdida*, [ISBN 9789588181608](#).
126. Oyuela Caicedo, A. (1986). "De los tairona a los kogi: Una interpretación del cambio cultural," *Boletín Museo Del Oro*, [ISSN 2462-9790](#), 17.
127. Goody, J. (2012). *The Theft of History*, [ISBN 9781107683556](#).
128. Axelrod, R., and Cohen, M. (2000). *Harnessing Complexity: Organizational Implications of a Scientific Frontier*, [ISBN 9780465005505](#).
129. Hobsbawm, E. and Ranger, T (eds.). (2012). *The Invention of Tradition*, [ISBN 9781107604674](#).
130. Horgan, J. (1995). "From complexity to perplexity," *Scientific American*, [ISSN 0036-8733](#), 272: 104-109.
131. Langton, E. (1990). "Computation at the edge of chaos: Phase transitions and emergent computation," *Physica D: Nonlinear Phenomena*, [ISSN 0167-2789](#), 42(1-3): 12-37.
132. Rosen, R. (2000). *Essays On Life Itself*, [ISBN 9780231105118](#).
133. Wegner, P. (1997). "Why interaction is more powerful than algorithms," *Communications of the ACM*, [ISSN 0001-0782](#), 40: 80-91.

134. Solé, R.V., Manrubia, S.C., Luque, B., Delgado, J., and Bascompte, J. (1996). "Phase transitions and complex systems: Simple, nonlinear models capture complex systems at the edge of chaos," *Complexity*, [ISSN 1076-2787](#), 1: 13-26.
135. Garnier, S., Gautrais, J., and Theraulaz, G. (2007). "The biological principles of swarm intelligence, swarm intelligence," *Swarm Intelligence*, [ISSN 1935-3812](#), 1: 3-31.
136. Maldonado, C.E., and Gómez Cruz, N.A. (2009). "Facing N-P problems via artificial life: a philosophical appraisal," in *Advances in Artificial Life: 10th European Conference on Artificial Life ECAL*, [ISBN 9783642213137](#), pp. 216-221.
137. Dorigo, M. (2005). "Ant colony optimization theory: a survey," *Theoretical Computer Science*, [ISSN 0304-3975](#), 334: 243-278.
138. Casti, J. (1991). *Paradigms Lost: Images of Man in the Mirror of Science*, [ISBN 9780688081317](#).
139. Kampis, G. (1998). "Self-modeling systems: a model for the constructive origin of information," *Biosystems*, [ISSN 0303-2647](#), 38: 119-125.
140. Maldonado, C.E., and Gómez Cruz, N.A. (2014). "Biological hypercomputation: a new research problem in complexity sciences," *Complexity*, [ISSN 1076-2787](#), 1-11.
141. Maldonado, C.E. (2013). "Consecuencias políticas de la complejidad," *Iztapalapa: Revista de Ciencias Sociales y Humanidades*, [ISSN 0185-4259](#), 74: 189-208.
142. Gould, S.J. (1990). *Wonderful Life: The Burgess Shale and the Nature of History*, [ISBN 9780393307009](#).
143. Sole, R., and Goodwin, B. (2008). *Signs of Life: How Complexity Pervades Biology*, [ISBN 9780465019281](#).
144. Maldonado, C.E. (2007). "Política y sistemas no-lineales: La biopolítica," *Dilemas De La Política*, ISSN 2007-7890, 91-142.
145. Bedau, M.E. (2000). *Artificial Life VII: Proceedings of the Seventh International Conference On Artificial Life*, [ISBN 9780262522908](#).
146. Tiezzi, E. (1989). *Tempi Storici, Tempi Biologici*, [ISBN 9788879899703](#).