Visible Characteristics of Living Systems: Esthetics and Artificial Life

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Abstract

Until now Artificial Life has been a purely scientific and technological matter. The aim of this article is to show that it is also - and in a fundamental way - an esthetic, cultural and psychological issue which involves a rethinking not only of the relationship between living things and their environment, but of the whole notion of ecology. At the same time Artificial Life implies a rethinking of esthetics that excludes the idea of control and dominance. Living systems are autonomous in terms of action, but heteronomous in terms of representation, for to be a living thing means being considered as such by another living thing. This essential characteristic adds an esthetic and psychological dimension that has equal weight with the technological one; and one of the crucial questions in the field of Artificial Life is to establish exactly the visible characteristics of living things.

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1. Artificial Life as an esthetic problem

The difficulty we experience in grasping the esthetic dimension of what is termed "Artificial Life" (1) stems as much from the inadequacy of the standard esthetic categories as from the tricky business of coming to grips with what is involved in these technologies of living systems (2). However, the situation becomes clearer once we become aware of two things. Firstly, that the designing and making of animats (3) is a continuation and an intrinsic part of the evolutionary process and that it enriches and fills out the living whole of which it is an essential aspect; and secondly, that life and artistic practise are linked in a very special and intense way. Artistic practise can in fact now be perceived anew as the supreme companion of life, enabling it to see itself as living and to transform itself accordingly (4). The connection between esthetics and Artificial Life appears at that problematical point of convergence we call Evolution - which in fact is Co-Evolution, the simultaneous, interwoven and interactive evolution of the living and the made.

And so Artificial Life points up the coming together of esthetic procedures and the phenomenon of life via autonomy, cognitive interactivity and the relationship with the environment. The romantic definition of esthetics as the science of the beautiful can itself be explained using the categories of living systems and specifically the notion of parasitism, of the main trunk stifled by shoots rendered pathogenic by their sterility.

Our aim is to explore the development of Artificial Life within the continuity of Co-Evolution - of the relationship between life and its context - and to seek to discover the extent of the role of esthetics as a self-directed meditation by life on this Co-Evolution. Thus esthetics is conceived here as the thought-process by which life apprehends its own capacity to transform living systems and lives fully its role as an participant in the co-evolutive advance. Seen in this light esthetics becomes an intrinsic property of living systems, on an equal footing with reproduction or autonomy, and raises in the most forcible way imaginable the question of the place of life and intelligence in the biomass and by extension that of the place of man and autonomous artefacts in the universe.

2. Artificial Life at the meeting point of Ecology and esthetics.

The terrain of life is described in quite different ways by ecologists (5) and Artificial Life researchers. The former see the issue as explicitly ethical, the latter as implicitly esthetic. The former seek to save the past by the force of an idea, the latter to generate futures for which the ideas do not as yet exist. And while the former work in terms of a norm, the latter have gone beyond the norm and are out to smash or subvert it. In this sense artificial life is an anti-ecology: a lack of interest in the preservation of existing species goes hand in hand with a determination to overtake Nature, to create a profusion of natures in parallel with and more natural than - that is to say, perceived as more natural than - 'natural Nature'.

So we are faced with two ecologies. Ecology I is that of the ecologists, bent on the preservation of the past and of an entity whose status, as the French philosopher Clément Rosset has pointed out (6), is ambiguous. Ecology II, on the other hand, puts the emphasis on the harmoniousness of the relationships within a given space, without reference to any 'natural Nature' or any predetermined norm. Artificial Life draws on Ecology II; its approach includes a form of artistic practise experienced as an adaptive phenomenon and conceptualized as a free gesture characterized by the fact of being at all times the subject of a choice. Seen in this way art becomes a knowledge of knowledge, a technique of technique, a knowledge of technique. As part of one of the ecosystems of the living world, artistic practise is also one of the adaptive techniques man has come up with in response to changes within his environment and within himself. To Ecology I's anxiety concerning the disappearance of a world, Artificial Life responds with a multiplication of worlds. Going even further, it redefines the living

world as an organized system rather than a material entity and contests the ontological pre-eminence accorded to living things of the carbon-containing variety. It is symptomatic, too, that Ecology I speaks of Life and Ecology II, when possible, of living systems. We are emerging, maybe without knowing it, from the last of the Aristotelian categories that still seemed to be operative and it is this situation that makes an esthetic assessment of AL imperative. However, the growing tendency of AL researchers to define the living world as a specific kind of organizational system leads them to reduce it - wrongly in our opinion - to no more than this. The living world demands a certain level of autonomy, but other factors are involved too. Every living system is autonomous, but every autonomous system is not necessarily living. If we are to appreciate Artificial Life in all its complexity, depth and richness, we have to endow it with other properties capable of taking account of some of its most interesting characteristics - notably the development of living systems towards cognition.

Artificial Life can thus be taken as the first type of autonomous artefact added to the living world and to biology (7). While it is true that tools and ornamentation are artefacts added to living systems, they remain without any autonomy in this regard (8). AL, on the contrary, is an artefact added to living systems in general and not to any living system in particular; whence its specific character and the difficulty of finding equivalents for it. What it proposes, in fact, is an ecosystemic view of the destabilization of systems. All of a sudden the modelmaker is inside the model and the distinction between the two becomes of minimal importance compared to the potential generated at their interface (9). Thus a Lewis Carroll-style paradigm takes on an extraordinary relevance here; its logic is stronger than that governing common sense, whose glaring paradoxes it simply subsumes. Artificial Life introduces new parameters into the system, but without inducing its breakdown; at worst it gives rise to fruitful distortions which themselves intoduce deterministic subsystems into spaces essentially governed by chaos.The most efficacious AL systems are those containing perturbation as a normal part of their dynamics. Thus the growth tendency apparent in Artificial Life is not some sort of tumultuous baroque profusion of the Hieronymus Bosch kind, but rather the expression of the powerful principles of delegation, reappropriation and cooperation.

3. Forms of delegation, reappropriation and cooperation: the esthetic stakes in Artificial Life.

The generation of images can follow two main paths which must never be confused. The first approach is essentially Newtonian, with objects reacting to simple, classical questions and procedures belonging to physics. The second is more interesting. as it involves a morphogenesis governed by a more complex generative dynamics. Artificial Life offers artistic practise a way out of the Walt Disney trap, where the principle of delegation is entirely absent. The cartoon is no more than a representation of life: it is not even a simulation of it, much less an artificial life. In its Walt Disney form the cartoon is less rich than the life it represents, exaggerating a single isolated aspect at the cost of an impoverishment of the whole. Artificial Life, on the other hand. takes as its basic premises fictions richer than life, which as a consequence finds itself subsumed in the broader category of living systems; in other words AL reveals biological life as a province of a region much richer than was at first suspected.

Understanding the principle of delegation is essential and must work on two levels: that of notation and that of the process of algorithmic production. In both cases a joint creation of facts and meaning is involved and the outcomes can only be seized at the meeting-point of an empirical description and a hermeneutics: an empirical description because all these delegations produce objects and modify the processes, and a hermeneutics because the objects and processes are neither directly accessible to, nor totally graspable by even the subtlest or most complex reasoning. Multiple and repeated interactions with an environment subject to its own dynamics and partly dependent on the objects and processes concerned lead inexorably to areas of uncertainty and implicit

fractures. The difference between the two types of delegation lies elsewhere. The complexity of algorithmic delegation stems from repetitiveness, while that of the notational variety depends on recommencement. In the latter case the organism always chooses a new starting point, even when to some extent dependent on its earlier starting points. In algorithmic delegation, however, the process encompasses all the previous points of departure, although its use of them may only be partial. In contrast with oriental practise, western art has always favored non-algorithmic delegation processes such as notation. In this context, Artificial Life raises two distinctively new questions. Firstly, is it possible that there exist algorithmic principles of delegation indistinguishable from those more closely related to written notation, at least as far as an outside observer is concerned? Secondly, what kind of approaches would be needed to take as one's starting point delegation procedures of the same kind as the notational variety? In other words - and this is where the question really leads - can we conceive of interventions in respect of living systems which would be neither biological or medical, but which would remain part of the living world in the strictest sense of the term? This is what is at stake, esthetically, in artificial life.

Can one delegate a procedure in which one is directly involved? Can one face up to one's own delegation? In theory at least there is no problem. A political leader can find himself in conflict with his ambassadors, or a creator with his own creations. There is already an entire literature devoted to the subject - starting with the Bible! Seen from a certain point of view all generational conflict is a confrontation between an individual and the delegated creatures who are his offspring. Western culture has great difficulty in imagining the existence of multiple 'sources of life' in the same space, in the same world; and when it succeeds, it rejects the idea. An interpretation of witchcraft along these lines could be interesting, for the idea of a relationship with the Devil raises in a radical form the question of the legitimacy of life-principles outside the realm of the known. But whereas witchcraft and demonology see the matter in terms of a transgression of normality - as a question of perversion - Artificial Life treats it as an extension of normality (9). But delegation is a dual problem. It leads very quickly to a delegation of delegation, with the attendant risk of a bureaucratization of the living world following a fixed pattern that nobody can see the point of any more; and this bureaucratization persists, because of the history of the system. Thus the delegation of delegation engenders a very real obscurity which is intrinsic to the living world; and so the interpretation of the living world appears as inherent in the appearance of this obscurity. Biology is only conceivable from the moment living things come to life. In the same way Artificial Life simultaneously generates living systems and the biological wherewithal for interpreting them. Moreover, AL seen in this light becomes a direct competitor of biology, whose monopoly, already weakened by biochemistry, is now definitively broken!

Artificial Life researchers: the new Conquistadors

The delegation principle works via a reappropriation of the process by notation. Artificial Life researchers habitually give names to their creations, build up complicated typologies for them and come up with bold new syntactic designations for areas that are still terra incognita. They are the true successors of the Conquistadors of the 15th and 16th centuries, of the explorers of the 18th and 19th. A double stimulus drives them: a shared generating of interactive processes and a way of expressing this, of designating and conferring an identity on what they are doing. Having created his creature in real or virtual space, the researcher or artist-researcher tries to capture it with language and to master its imaginative dimension in such a way as to turn it into a usable object, one that can be proposed for comparison, criticism and reconstruction. Putting AL researchers on the same plane as the Conquistadors is not, then, a cheap provocation, for each draws his inspiration from a voyage into the unknown. In both cases this voyage is at least as much intellectual as physical and is underpinned by a body of knowledge that is at once indispensable and fundamentally inadequate. This is not to say that it is useless, far from it, but it systematically falls short of what is taking place

and of what the explorers encounter. The new world of the Conquistadors was cultural and geographical, but that of AL researchers is cultural and technological. We stress the cultural dimension here, for AL researchers are dealing not only with technological problems, but with a whole cultural and conceptual problematics. What is the living world? What is cognition? What sort of relationship does an adaptive organism maintain with a complex environment in a perpetual state of change? The answers to these questions shape a culture. The discovery of the New World in the 15th century meant that Europe could never be the same again; given the creation of 'intelligent artefacts', can we really believe that our world will remain unchanged? However a major difference clearly separates the Conquistadors from the AL researchers of the late 20th century. The former were crossing a pre-existing region, a land that had lived without them for centuries and which was endowed with an extremely rich life of its own. The situation of AL researchers is different and more ambiguous, for they are exploring intellectual and technological territories that they have to create as they go along. Yet the Conquistadors also saw themselves as exploring a land that was very largely that of their dreams, hopes, fantasies and long-held desires; thus they developed a relationship with the past akin to that of AL researchers, who draw on an extraordinarily rich cultural, intellectual and technological past which no-one has yet exploited to the full and of which they are equally inheritors and creators. Artificial Life researchers are in a very similar position to that of the 19th-century French painter Lesieur who, having begun to depict jellyfish in his works, went on to become a major specialist in the subject; or of the entomologist Fabre, who took up water colors in order to portray insects and became the greatest water-colorist of the 19th century. The creative process takes place in the context of a delegation that is in part sought out and in part accepted.

In relation to delegation, the very notion of exteriority is problematic. Is every outcome of Artificial Life capable of delegating and of confirming its initial project in the objects thus delegated? Is there some kind of coherence here?

5. Artificial Life and the refusal of the urge to control inherent in western esthetics

The western view of art suffers from an urge towards control in relation to the creation of the object, in contrast with the eastern approach, which has always accorded the physical act of creation a decisive role. In this respect Artificial Life researchers are following a path resembling what we might call the oriental way to interaction with the real.

The dynamics of the joint process of delegation and reappropriation in Artificial Life is in fact very close to that of calligraphy. Could AL be a future form of calligraphy? At one level AL describes itself very aptly as the abstract gesture by which life projects itself on to a representation of itself which is both more and less than itself. Notation fundamentally constitutes a memory of the trace left by the living world, a memory endowed with a life of its own (to use an expression that is, perhaps erroneously, always taken figuratively). A 'coffee-stain' esthetics is in the process of emerging within Artificial Life, which recognizes that man only partially controls the dynamics of his productive output. Indeed, it would be more accurate to describe man as a precondition of creation rather than as a creator in the strict sense.Thus an esthetics of partial action emerges from an activity mistakenly regarded as essentially technical. While man is the objective cause of the work in the process of being produced, he cannot say exactly what he is going to make for he can anticipate neither the the path that will be taken nor the final result. Thus he takes on a blind responsibility, one which leads to a blind man's esthetics, an esthetics of partial vision founded ultimately in sensory and perceptual surprise. Man becomes incapable of mapping a universe of possibilities which go beyond his imaginative capacities in a world in which his immediate means of action exceed his imaginative power. Compared to his practical possibilities his imagination is crippled. Accustomed to seeing himself above all as powerful, he is stupefied to discover that his true wealth lies in his weaknesses and

limitations. The AL researcher finds himself, then, in the situation of the Japanese artist gathering driftwood on the beach: his art is no longer the result of his productive capacities, but rather of his discernment, judgement and observation. For the first time, and thanks to Artificial Life, western man is discovering the possibility of being an artist without having to produce. The artist is rediscovering his medieval role as an artisan - but this time as an artisan of life. Or more exactly, of lives: lives which are far from existing in parallel since, on the contrary, they give rise to a multiplicity of points, not of intersection, but of adhesion and fusion. Thus we arrive at the notion of an esthetics whose relationship with the beautiful is strictly contingent. The generation of non-functional associations and of the pleasure they evoke becomes paramount once again. In such a context labels lose the simplicity they had in the classical epoch and an artist can now easily be a biologist or a computer expert. Seen in this light AL is an intrinsically esthetic phenomenon. Thus the living world generates a specific emotion via a characteristic impulse, that of intentionality - and it is no accident that this is one of the impulses that Artificial Life puts so much energy into evoking.

6. Man: a living thing incapable of identifying living things.

The esthetic side of Artificial Life gives rise to a major problem which up till now has always been regarded as scientific, when in fact it is first and foremost esthetic: that of recognizing an object as a living entity. When can I say of an object that it is a living thing? When am I ready to recognize an artefact as a living thing? These are fundamental questions for Artificial Life, one of whose primary concerns has always been to generate living systems as alive as those existing in nature - and even more so. Such an aim is only realizable if we take advantage of an intrinsic weakness of living things: their difficulty in accurately identifying other living things. Living things are always ready to grant this status to artefacts (11), but according to what criteria? What allows a living thing to be recognized as such, or an artefact to be perceived as a living thing? Finding an answer to this question will be one of the major tasks of esthetics at the dawn of the 21st century - and the answer will surely not take the form of a mental model. It is becoming more and more evident that the definition of living systems is a matter not only of engineering and biology, but also of esthetics. To be a living thing is not only to possess a given set of functional or biochemical characteristics, for it also carries the fundamental implication of being recognized as living by other living creatures, to be accepted into the midst of other living creatures. The recognition of living things is at first perceptual rather than intellectual, sensual rather than rational. Here 'vibes' take precedence over reasoning. A Cellular Automaton, for example, is not going to fool anybody : it is not living, it just behaves asymptotically as if it is. The sight it is endowed with is purely instrumental and deceives no one. This is to say that each human being has a biological and a cultural memory and that it is at their interface that he recognizes the biomass.

Man himself is a living thing who has trouble identifying living things and has to use a machine in order to do so. But he is also a living thing who cannot live without creating representations of the living world. Prehistoric art is primarily an art of living beings applied to the living world; it is symptomatic that before undertaking any other representations prehistoric man chose to paint the living world (12). What lies behind this need? The possible explanations are many, but one of the most intriguing has to do with man's total inability to engage in dialogue with the non-human living world. The different species are mute in relation to each other, for what takes place between them is primitive in the extreme: mere signals or affects, which are certainly not complex communications. Humanity is not well suited to this silence between species and the impossibility of resolving the problem is a source of considerable suffering. The inability to communicate with the living world is one of the great human tragedies and leads to an intense questioning which continues to loom very large: if, for example, extraterrestrial life exists, what is the likelihood of our being able to recognize it? It is not at all absurd to wonder whether machines might represent the sole viable interface in such an area. This is the veritable principle of delegation and doubtless the most

frightening of all; its consequences are going to demand more detailed exploration.

7. Life only exists in a context in which life is already present

It is clear from what has already been said that the potential fertility of Artificial Life is the result of a conceptual shift whose precise extent remains to be determined: Artificial Life has in fact shifted imperceptibly from the field of life to that of living systems. In doing so it has left the question of the characteristics of life to one side, for those of living systems seem to it more important. One stands out in particular: a living system is a form of organization governed by other living things. In this sense the very discussions in the field of Artificial Life have an evolutive value which supports the thesis that we are already in the presence of artificial living things; let us not forget that eminent researchers already declare themselves satisfied with their results.

A consequence of this observation is that a system is living only if another living system already exists. To be living means to be so in the context of the 'representation' of the living world created for itself by another living thing. Two notions of autonomy need to be distinguished here: autonomy of movement and autonomy of representation. To stress autonomy of movement is to render explicit the idea that a system can only be considered autonomous from the moment when it can act without reference to any external will. Autonomy of representation is the idea that a system is autonomous from the moment when it develops without the need for a representation of itself as an autonomous entity, whether such a representation comes from itself or from other systems. We hold that in the case of the living world we are involved with systems endowed with autonomy of action but not of representation. In doing so we part company with von Neumann - and with all classical computer science, which stresses autonomy of action but fails to consider autonomy of representation. (The notable exception here is Alan Turing, whose test has never received the recognition it deserves, inasmuch as in respect of intelligence the question of autonomy of representation was certainly raised there - along with the implicit conclusion that an intelligence is only an intelligence from the moment when it is acknowledged as such by another intelligence.) A whole part of the controversy about the possibility of artefacts' being living systems stems from this confusion. We are now ready theoretically to grant the status of living things to systems, but in practise we find this unacceptable.

8. What are the visible characteristics of living things?

So what do we need in order to be satisfied? The answer is obvious: we want the visible characteristics of living things, and this for psychological reasons that can be considered as specific to the realm of the living. We prefer to grant the status of living things to entities which appear to be living even though they are not, rather than to entities having all the characteristics of living things - except that of looking like them. This said, an obvious issue is that of establishing the visible characteristics of living things. It must be stressed that this is a psychological and esthetic question and not a biological one - at least not in the classical sense. There are at least two kinds of visible characteristics of living things and it is important, at least initially, to separate them: they can be physical or cognitive.

The physical characteristics are those which allow us to know on sight that we are dealing with a living thing and not a non-living thing, such as a mineral. The cognitive characteristics can be considered on distinct levels. The first level, purely reactive and present in all living things, shows up in response to certain situations - a burn or a sudden burst of bright light, for example - and more generally to all outright aggression. Living things have an inherent reaction to aggression. The second level is strictly cognitive: the organism does not settle simply for reacting to aggression or to a signal, but also processes information in terms of a given aim. Here we are talking about intentionality. A third level is found only in the most complex organisms, which

not only process information, but generate innovation; that is to say, they find a means - usually ecological - of coming up with new messages and behavior. This level is inherently self-reflexive and leads to co-performance processes that are directly applicable to the problem of the esthetic dimensions of Artificial Life.

A highly-evolved living thing such as man will only regard himself as dealing with another living thing when faced with an entity possessing at least some of the physical and cognitive characteristics enumerated above.

9. Conclusion

Given the importance of the principle of delegation in the make-up of Artificial Life, it is astonishing that researchers in this field do not go in for delegation at all. The situation is close to paradoxical: here we have an AL researcher who is pushing the frontiers of the universe to their limits, adding other lives to life, but at the same time shutting himself away behind a set of conventional frontiers - those of his self and his profession - which he manages to make virtually impassable. What do know of the Artificial Life researcher - except that he is an Artificial Life researcher? Whence the question: how can the Artificial Life researcher generate creatures which he will perceive with perfect clarity, when he has no clear vision of himself, when he builds himself around a primeval darkness, around a blind spot of which he himself has only a vague awareness? An ironic aspect of Artificial Life emerges here: man has developed a mechanistic view of nature, in the belief that he would thus bring total clarity to the living world. The result has been very different: he has rendered the artefact obscure, to the point where he can describe it as living.

Notes

(1) Artificial Life in the sense of the area of study that C. Langton is trying to define in his workshops at the Santa Fe Institute. cf. C. Langton, 1989, Artificial Life, Addison Wesley.

(2) This article is devoted to a consideration of the esthetic, anthropological and psychological dimensions of artificial systems as they figure in 'Virtual Reality' and 'Artificial Life', presently under discussion at CYPRES, in Aix-en-Provence. Certain aspects of its content have already been presented elsewhere, in, for example, L. Bec, Epistémologie fabulatoire, in: C. Langton (ed.), 1992, Artificial Life II, Addison-Wesley; and D. Lestel, 'Artificial Life comme synthèse des arts vivants' (submitted for publication).

(3) cf. J. A. Meyer & Wilson, 1991, From Animals to Animats, Cambridge: MIT Press.

(4) Of course, this view of artistic practise is not completely new. The premises of such a position can be found in the paper by Gregory Bateson, 1967, Style, Grace and Information in Primitive Art, given at the Wenner-Gren symposium on primitive art, 27 June - 5 July, Burg Warenstein, Austria. It also appears in G. Bateson, 1972, Steps to an Ecology of Mind, New York: Chandler Publishing Company. Even if the paper is fairly superficial, it raises certain basic ideas, in particular in its approach to art as a key element - although still a poorly conceptualized one - in the evolutionary process.

(5) We are of course well aware of the enormous variety of ecological movements. But all of them, or just about all, see nature as an entity to be protected.

(6) From among the works of this prolific writer a useful book in the present context is Le réel : traité de l'idiotie, Paris: Editions de Minuit, 1977.

(7) We speak here of the living world and biology since Artificial Life is working at the the interface of the two and is not orientated solely towards the living world.The conceiving of additional worlds demands a consideration not only of what the living world is, but also, as we shall see further on, of how living things apprehend and conceive themselves, especially via other living things; biology is one of the possible paths to follow here. Nevertheless, this essential dimension of Artificial Life goes unnoticed by the great majority of researchers. Philippe Quéau addressed himself to the situation, but at once deprived it of all its rich potential: in an otherwise extremely interesting article ('Les vertus et les vertiges du virtuel', Art Press, 1991, Special issue: Nouvelles technologies : un art sans modèle? pp 162-168) he suggests the term 'virtual simulation' for the new computer-assisted images, since the notion of virtual reality strikes him as inadequate and misleading. The problem he raises is an interesting one but his idea is no solution, for he does not succeed in imagining that the simulation stage is already in the past.

(8) Concerning ornamentation, cf. the thoughts and the attempt at synthesis of the anthropologist Jean-Thierry Maertens , 1978, Ritologiques, Paris: Aubier.

(9) The mirror-modeling of bumblebee societies by Hesper and Hogeweg already concedes the crucial role of the observer. A more recent work by J. Varela, E. Thompson & E. Rosch, 1991, The Embodied Mind: Cognitive Science and Human Experience , Cambridge : MIT Press, suggests approaches very similar to those rather hastily mentioned here. These studies are in the tradition of Maturana and Varela's work on the biology of cognition, which brings to the fore the benefits to be gained by taking account of the knowing-subject/context pairing as an aid to understanding the phenomenon of cognition.

(10) We have neither the time nor the space to develop here the ideas emerging from this. The question of delegation as a transgression of the normal crops up repeatedly in cultural history in a host of different forms and modes, including witchcraft, shamanism and the use of psychedelic drugs. Artificial Life picks up this idea of a living world conceivable as other than 'natural' and its esthetics raises once more the question of the kind of relationship a speaking being such as man can have with these new creatures and these 'other worlds' situated beyond strange frontiers. On the subject of witchcraft, shamanism, hallucinogenic plants and the crossing of the frontier separating humans from animals, cf. Michael Harner, 'The Role of Hallucinogenic Plants in European Witchcraft' in: M. Harner (ed.), 1973, Hallucinogens and Shamanism, London: Oxford University Press, pp 125-150.

(11) This fundamental characteristic of living things has received surprisingly little attention, notwithstanding the abundance of references available on specific aspects of it - mimicry for example.

(12) One can usefully refer here to the remarkable work of Leroi-Gourhan, who undertook a comprehensive quantitative study of the content of primitive rock paintings.

English translation: John Tittensor