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Complexity, Creativity, and Society

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Science is engaging with new ways of understanding and relating to the world of complex and unpredictable phenomena. This article explores some biological and social implications.

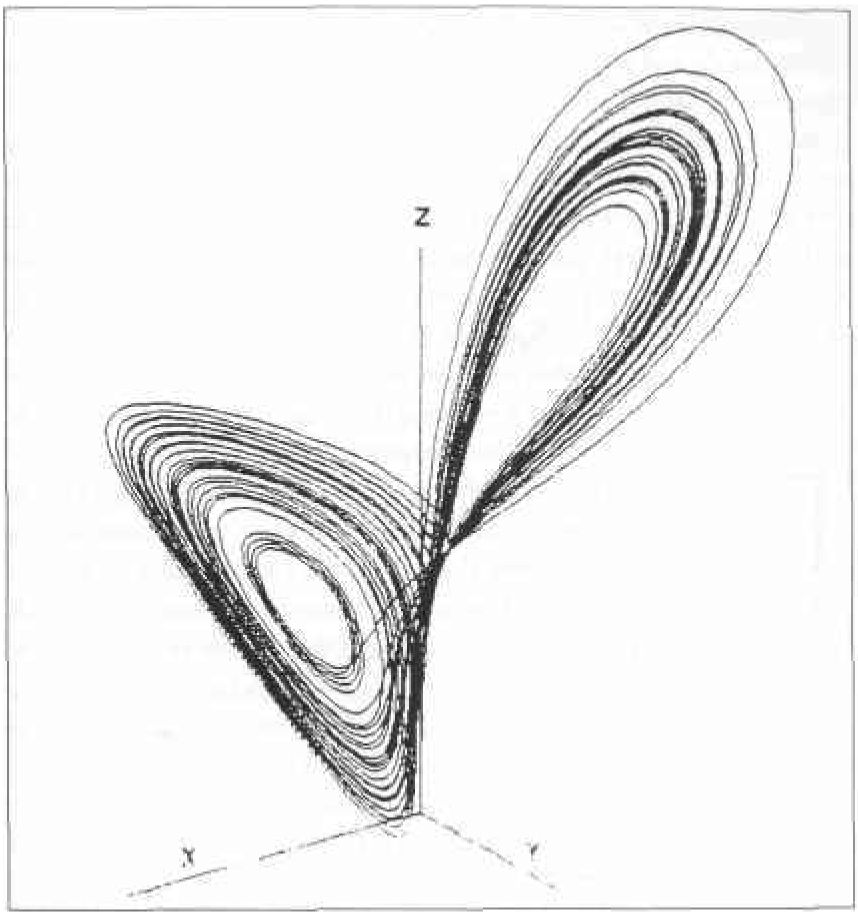
Every once in a while the dialectic of science carries ideas in unexpected directions that connect with wider social movements, revealing the deeper relationships between the two. Current concerns about health, environment, community structure and quality of life in general (as opposed to quantity of consumer goods), all reflect shifts of focus: from the individual to relationships and the collective, the part to the whole, and from control of quantity to participation in quality. This article is about new ideas in science that are connected with the recent remarkable proliferation of books and articles on chaos and fractals and their relevance in diverse areas of science and society. The broader context of these developments is the study of complex systems, which we all know are the reality which we experience, rather than the simple models of reductionist science. So, in a sense, science is finally coming of age, and as it does so it is going through some fundamental soul-searching. There is no consensus yet about where we shall end up, except that it will definitely be somewhere else. What follows is my own assessment of the significance of the new developments for the future of science and some of its social consequences.

The discovery of strange attractors

Complexity has a multitude of colloquial meanings, none of which corresponds precisely to its use in the area of study that has come to be known as the science of complexity. There, it refers to the potential for emergent order in complex and unpredictable phenomena. This science grew out of puzzling problems concerning planetary motion that were uncovered by the great nineteenth century mathematician and physicist, Henri Poincare. He noticed that something as apparently simple as three bodies interacting, such as sun, earth and moon, gave rise to very strange dynamic motion that appeared to carry a distinct signature, a pattern that had new and unforeseen properties. Working out the precise characteristics of that signature has occupied mathematicians for nearly a century.

However, the study of a rather arcane problem in planetary dynamics is not itself sufficient to bring mathematics to the attention of millions: the maths has to connect with human experience. This connection was made when Edward Lorentz, a meteorologist at the Massachussetts Institute of Technology, discovered the same complex behaviour as Poincare had while studying, in the 1970s, the solutions to equations describing weather patterns. The difference was that Lorentz had a computer, so that he could get it to trace out the solutions on a screen. Using Poincare's method of mapping complex dynamic patterns, he observed a new and beautiful mathematical object, now known as the Lorentz attractor (see opposite).

Lorentz realised that he was dealing with a radically new type of behaviour pattern whose properties led him to an immediately graspable metaphor: a butterfly flapping its wings in Iowa could lead, via the strange dynamics of the weather, to a typhoon in Indonesia. Stated in another way: very small changes in initial conditions in the weather system can lead to unpredictable consequences, even though everything in the system is causally connected in a perfectly deterministic way. The way this works in relation to the diagram is as follows. Suppose you choose any point on the tangled curve in the diagram as the starting point, corresponding to some state of the weather. This will develop in a perfectly well-defined, though complex, manner, by following the curve from the (arbitrary) starting point in one direction, which is prescribed by the equations. Every successive state is clearly defined - i.e. everything is perfectly deterministic, since this is what dynamical equations describe. However, suppose there is a small disturbance that shifts the weather to a neighbouring part of the system, to a point on a nearby part of the tangled curve. Then, comparing the



The Lorentz attractor

state of the initial weather system with that of the disturbed system as they both develop along the curve, a basic property of the strange attractor is that they move away from each other exponentially fast. That is, knowing what the weather is now is no predictor of what it will be a couple of days hence, because tiny disturbances (the butterfly effect) can produce exponentially divergent behaviour. This is the signature of deterministic chaos, now identified in a great diversity of mathematical equations whose dynamic properties are described by strange attractors, of which Lorentz' attractor is an example.

The consequences of this mathematical discovery are enormous. Since most natural processes are at least as complex as the weather, the world is fundamentally unpredictable in the sense that small changes can lead to unforeseeable results. This means the end of scientific certainty, which is a property of 'simple' systems (the ones we use for most of our artefacts such as electric lights, motors, and electronic devices, including computers). Real systems, and particularly living ones such as organisms, ecological systems and societies, are radically unpredictable in their behaviour, as we all know. Long-term prediction and control, the hallmarks of the science of modernity, are no longer possible in complex systems; an appropriate relationship to them is to participate with sensitivity in their unfolding, since we are usually involved in their dynamics in some way. Insight into the processes involved is now assisted by a precise hypothesis about what may underlie this complexity: they may all live dynamically on strange attractors, obeying dynamic rules that lead not to stereotyped but to unexpected behaviour.

This is where another aspect of the complexity story enters. A typhoon may well be the unforeseen consequence of the butterfly innocently seeking nectar in the fields of Iowa. But a typhoon is not itself a chaotic weather pattern: it has a highly organised dynamic structure. That is to say, a typhoon is one of the possible patterns that emerges from the complex behaviour of the weather system. So the dynamics of the weather combines both order and chaos. They live together. Although we cannot predict what will be the consequences of a small disturbance, we do know that one of a limited set of possibilities will follow - a typhoon, a high pressure region with sunny skies, a low pressure front with rain, and so on - a large but not indefinite set of possible emergent patterns. This is the signature of *complexity.*

Complexity and the edge of chaos

This approach to understanding complex processes is now being applied to many areas of study: to evolution, for instance, to economics, and to the dynamics of social change. All of these combine unpredictability with order in distinctive ways. Organisms of different species - kestrels, badgers, oak trees, columbines - all have distinct properties that express a specific intrinsic order that we use to recognise them as a 'type', a species of organism. However, both the emergence of these species in the course of evolution and their extinction are fundamentally unpredictable events. Developing models of these processes is the concern of 'complexologists' interested in biological phenomena.

The same approach can be used to study physiological activities *within* organisms, looking at the dynamics of the immune system, for example, or of the heart. Medical cardiology is undergoing something of a revolution as a result of applying ideas from complexity theory to the study of normal and abnormal heart beat patterns. Nothing is more orderly than the rhythmic beating of your heart as you sit reading this, you might think. It is the paradigm of physiological regularity on which your life depends in a most immediate way. However, combined with this order there is a subtle but apparently fundamental irregularity: in healthy individuals, and particularly in young children, the interval between heart beats varies in a disorderly and unpredictable way. If the interbeat interval is regular - either constant or itself rhythmic - then this is a sign of danger, indicating that the heart may be prone to fibrillation leading to cardiac arrest, or some other arrhythmia. Cardiologists such as Ary Goldberger, working at the Beth Israel Hospital in Boston, consider that the healthy heart beat is embedded in a sea of chaos which both reflects its sensitivity to the activities of the rest of the body and its capacity to respond appropriately to the continuously varying demands made upon it as we go about our diverse activities and experience different emotions. Too much order in heart dynamics is an indicator of insensitivity and inflexibility, just as rigidity in other patterns of behaviour indicates stress and incipient danger. An intuitively attractive idea follows: complex adaptive systems function best when they combine order and chaos in appropriate measure.

'Complex adaptive systems function best when they combine order and chaos in appropriate measures'

This idea was in fact one of the earliest suggestions to come from the analysis of complex systems. While studying the dynamic behaviour of cellular automata, which are particularly useful for modelling complex systems, Norman Packard and Chris Langton had the insight that the 'best' place for these systems to be so that they can respond appropriately to a constantly changing world is at 'the edge of chaos'. Here order and disorder are combined in such a way that the system can readily dissolve inappropriate order and discover patterns that are appropriate to changing circumstances. This fertile suggestion has been subject to severe criticism, as should any proposal that attempts to capture a generic property of a whole new class of systems. However, the basic idea that creative, adaptive systems are most likely to function best at the edge of chaos is proving to be a robust insight, despite the difficulty of pinning it down precisely (mathematically, logically). One of the foremost contributors to the elaboration of this concept in a variety of contexts, all of which relate to basic biological processes such as the origin of life, gene activity patterns in organisms, and the evolution of species, is Stuart Kauffman.[1]

From competition and survival to creativity

There is a very interesting paradox about evolution that emerges from this approach, which has significant social resonances. In the Darwinian perspective, what drives evolution is competition for scarce resources between organisms that differ from one another in their 'fitness', their capacity to leave offspring. The survivors of this struggle are the better adapted, those that can function better in their environment. However, the evidence from studies of species emergence and extinction during past geological ages, and from models that simulate these processes, is that species do not become extinct because of failure to adapt to changing circumstances, or because of cataclysmic events such a meteorite impacts or volcanic eruptions. Although these have undoubtedly contributed to the disappearance of species - the dinosaurs, for example - it appears that there is an intrinsic chaotic component to complex systems such as interacting species in ecosystems, which results in intermittent extinctions that vary from small to large, with a characteristic distribution; and these occur independently of the sizes of external perturbations. As David Raupput it: species go extinct not because of bad genes but because of bad luck.[2] There seems to be an unpredictable dynamic to creative processes such as evolution that involves inevitable extinction or destruction with a characteristic pattern of survival that is not due to individual success or failure but to the interactive structure of complex processes. The game of life, we might say, is one of creative emergence and extinction; the reward is not long-term survival but simply transient expression of a coherent form, a revelation of a possible state of life which we call a species, whose value is intrinsic to its being.

Clearly the metaphors are shifting here, from competition and survival to creative emergence and expression of appropriate novelty. These are not necessarily in conflict. They express different ways of seeing complex processes, the latter viewing the dynamics of the whole while the former expresses the perspective of a part. In fact, the science of complexity has been characterised as a holistic science which seeks to describe the properties of complex wholes. For example, whereas a

1. Stuart Kauffman, *At* Home *in the Universe,* Oxford University Press, Oxford 1995.
2. David Raup, *Extinction: Bad Genes or Bad Luck!* Norton, New York 1991.

knowledge of parts and their malfunction gives the medical model of disease, a study of the dynamics of the heart described earlier provides an example of how one can assess the health of the whole body from a study of the behaviour of a part, the pattern of the heart beat.

Diagnosing the state of the whole from a study of a part is of course the procedure used in a variety of complementary therapies, such as pulse diagnosis for acupuncture treatment, reading and treating the body via the feet as in reflexology, and so on. It is the traditional therapeutic approach. The science of complexity may provide useful diagnostic procedures based on a similar conceptual model, in which the relationship between whole and part is so intimate and integrated that the dynamics of the part reflects the condition of the whole body. However, the concept of a whole within the science of complexity is something new and involves an apparent contradiction. Because of the mixture of order and chaos that is involved within a complex whole, the parts simultaneously have significant freedom while expressing order. Put metaphorically, the next heart beat can occur whenever it likes (i.e. whenever the heart 'decides' is the appropriate moment within the current situation that it experiences within the body, and in terms of its own complex dynamics). The only constraint is that there be an overall average rate of beating for any particular physiological state (sleeping, sitting, running, together with the emotions experienced). More precise statements of this paradoxical condition of maximum freedom of the parts, together with coherence of the whole, can be given in terms of entropy, and concepts derived from the quantum mechanical definition of coherent states.[3] This holistic view has developed independently in a variety of contexts, including quantum mechanics itself.[4]

Creativity and society

These concepts are now being applied to a range of complex processes, from ecosystems to social organisations. Business corporations have been among the first to see the potential relevance of these ideas to management structure and creative organisational change. Since their everyday experience is 'living on the edge', any insights into dynamic structures that facilitate adaptive response are welcomed. The suggestions of complexity theory for business practice are a flattening of the management hierarchy, distribution of control throughout the system with fluid

3. Mae-Wan Ho, *The Rainbow and the Worm,* World Scientific, Singapore 1993.
4. David Bohm and Basil Hiley, *The Undivided Universe,* Routledge 1993.

networks of interaction between the parts, and the necessity of periods of chaos for the emergence of appropriate new order. The move towards a more anarchic, spontaneous dynamic is clearly threatening to the controlling manager, but it appears to be the path to creativity and diversification. This in no way guarantees survival, just as there is no long-term survival granted to adapted, adapting species in evolution. What it allows for is innovative expression, which has intrinsic value for the members of the enterprise, as well as providing the best chance of the organisations persisting in a constantly changing corporate world. All the participants in this sector of social organisation can then experience a higher quality of life, since they have greater freedom, more opportunities for creative play, and richer interactions - good for them and good for the organisation. The primary goal would not then be to survive through maximisation of profits, but to make possible a fuller and more creative life for all members of the company and thus to maximise the chances of appropriate collective response to perpetually changing circumstances. The shift of focus here is towards quality and away from quantity as the goal of a more mature society. In fact, the science of complexity may be seen as a significant harbinger of change, from the dominant science of quantities that has characterised modernity, towards a science of qualities that is emerging in the post-modern era.[5]

Naturalistic ethics

This shift of perspective in science clearly has many implications for our understanding of the natural world and our relations to it. One of the most profound concerns the relationship between scientific knowledge and ethical action. Logical positivism, the philosophical basis of empirical science, which rose to dominance in the early twentieth century, completely severs any connection between 'facts' and 'values' by asserting that no human mental components should contaminate the pure observation of reality by the senses. Rom Harre is a cogent critic of logical positivism, arguing both that it stifles science, and that it is immoral. He comments:

> It was positivistic in that it restricted the content, source and test of scientific knowledge to the immediate deliverance of the senses. It was logicist in that it confined the task of philosophers to the laying bare of the logical form of finished scientific discourse. The immoral character of this viewpoint hardly

5. Brian Goodwin, *How the Leopard Changed Its Spots,* Weidenfield and Nicholson, London 1994.

> needs spelling out these days. It is highlighted, for example, in Habermas's protest against the importation into human management of those favourite concepts of the positivist point of view, 'prediction' and 'control'. It is the animating philosophy of the morally dubious authoritarianism of Skinnerian psychology.[6]

Harre's philosophy of science is a form of realism in which explanation of phenomena depends upon the construction of models or theories that go beneath the level of appearance, to the generative processes that describe the real underlying causes of phenomena. An example of this is the theory of fluids (liquids, gases) that is used to describe the phenomena of the weather. The theory of fluids - like other similar approaches to science - uses the fundamental concept of a field, a domain of relational order in which the state of one part of a fluid is connected by a precise mathematical relation to the states of neighbouring parts; so that the whole weather system consists of a single three dimensional field which unfolds in time according to particular laws. Similarly, Poincare's original studies on planetary dynamics involved the use of gravitational field theory to describe the motions of three interacting bodies as an integrated whole.

This is the basic stuff of science, and Harre is actually rescuing its philosophy from an aberration. But he has added some distinctive components, in particular a rethinking of causality in science.[7] This allows us to escape from the curious impasse imposed by David Hume, in which we are unable to perceive necessary causal connections in natural processes and can do no more than register correlations between causes and effects, which at any moment could change. This is the ultimate fragmentation of atomism and the denial of our ability to participate in and grasp natural processes. Harre and Madden restore the notion of causal powers to nature, which is then reinvested with 'powerful particulars', which underlie the appearance of specific structures such as the motion *of* the planets, weather patterns, and the strange attractors of chaotic dynamics. These powerful particulars are the real underlying causal powers of natural phenomena, particular to each type of field, such as the force of gravitational attraction, of electromagnetism, or of fluid dynamics.

With the concept of generative processes comes the concept of natural kinds, those structures that we identify as having distinctive types of intrinsic order such

6. Rom Harre, *Varieties of Realism,* Basil Blackwell, Oxford 1986, p21.
7- Rom Harre and Edward Madden, *Causal Powers,* Basil Blackwell 1976.

as the elements in physics (carbon, copper, gold, etc), weather patterns (such as typhoons), and species of organism (kestrels, badgers, oak trees, human beings, etc). This argument is developed with clarity and force by Roy Bhaskar in books that develop the realist philosophy of science in both the natural and the social sciences.[8] With the concept of natural kinds comes a naturalistic ethics. This depends on our relationship to what we take to be the truth, insofar as science reveals it to us, and is counterposed to the excessive relativism of much postmodern theory which is disabling for both science and for ethics. If we believe that we have some insight into the true nature of something, then this influences our behaviour towards it. For example, if we believe from the evidence that certain foods are beneficial to human health and others are detrimental, and we are in a position to influence diet, then we will experience some compulsion to encourage the consumption of healthy rather than unhealthy foods. If we believe that children have a basic need to play (i.e. this is a necessary expression of their nature), then in general we allow space and opportunity for them to play. Likewise if, from close examination and study of the behaviour of chimpanzees, particularly in the wild, we become convinced that to express their natures they need conditions such as life in social groups and an environment with adequate freedom of movement, then we will discourage the confinement of chimps in isolation or in severely restricted circumstances. The same type of argument holds for whatever understanding we may have of any other species.

Andrew Collier, discussing these issues in an admirably clear book, puts the argument for the social sciences as follows.

> Social sciences, then, generate practical emancipatory projects by showing there to be (a) a need, (b) some obstacle preventing its satisfaction, and (c) some means of removing this obstacle. This is not a matter of mere technical imperatives, coming into play only *if you* want the projected good; given that a social science can tell us not only about the means of satisfaction but also about the need itself, it may ground *assertoric imperatives,* i.e,. since you need this, remove that obstacle thus.[9]

8. Roy Bhaskar, A Realist *Philosophy of Science,* 2nd edition Harvester Press, Brighton 1978; and *Scientific* Realism *and* Human Emancipation, Verso, London 1986.
9. Andrew Collier, *Critical Realism,* Verso, London 1994.

Furthermore, according to Bhaskar, 'for emancipation to be possible, knowable emergent laws must operate', thus linking us back firmly into scientific realism.[10] This is necessary because without principles of emergent order from complex systems there is no real nature that is expressed and nothing intelligible for us to understand, everything being totally accidental and contingent. Then all possibilities would have equal logical status, and we could rationally argue that there is no violation involved in depriving children of play and requiring them to work; or that we can design chickens and cattle to have extra muscle which prevents them from moving 'naturally', since we can also design cages that can support them. The realist argument also connects directly with the programme of research in the sciences of complexity, in which a primary goal is to understand the generative processes that give rise to the diverse forms of emergent order that arise in evolution (biological and cultural).

It thus becomes clear that the move from control and manipulation of nature, to participation in and understanding of the creative expression of nature in emergent forms, has significant consequences in a variety of contexts. Among these are our relationships with the environment and our use of plants and animals as commodities for manipulation by genetic engineering and biotechnology. The realist argument that different types of organism have natures means that, insofar as we understand these natures we are in a position to remove obstacles to their expression." Only when organisms are able to express their specific natures will they be healthy. If we are to consume these organisms (lettuces, cabbages, fish, etc) as food, then food quality depends upon the health of the organisms and hence on the conditions under which they live.

We are currently manipulating species more and more, both through changes in their environments (soil conditions, use of fertilizers, herbicides, pesticides, etc) and their genes, in order to increase quantity (of product and of money). In so doing we are disturbing complex systems in unpredictable ways that result in epidemics such as BSE in cattle and innumerable food allergies. We are pushing species to the brink of their stability, where they suffer disease, such as the increased mastitis in cattle treated with growth hormone to increase milk yields. What is so absurd about this example is that milk production was adequate before the new

10. *Bhaskar, Scientific Realism and Human Emancipation,* see note 8.
11. These ideas are developed in Gerry Webster and Brian Goodwin, *Form and Transformation,* Cambridge University Press, Cambridge 1996.

technology was introduced, so it was quite unnecessary. Quantity goes up, quality goes down, and these complex living systems are driven beyond their intrinsic stability (their natures) into states of propagating instability that manifest as epidemics and disease.[12] Frequently there are alternatives to these processes that are ecologically safe and maintain health; but, because they are not patentable, they are not attractive to the food industry. Biotechnology has a role to play in food and drug production. But companies need to act responsibly, with adequate biosafety controls and regulations. These may well require periods of testing to extend beyond ten years, because of the slow response times of complex genetic networks and gene transfers between species in ecosystems, which need to be studied intensively under controlled conditions before transgenic varieties are released. Without these, human health, and that of the ecological networks on which we all depend, will be put continuously at risk, with periodic devastating epidemics. In the past, only litigation after severe damage has forced responsible behaviour. The more sophisticated understanding of complex systems which is now emerging encourages us to take precautionary measures to avoid such disasters, reflecting sensitive participation in the processes in which we are immersed, rather than continuing with the fiction that we can exert control from the outside as objective, detached observers with predictive knowledge of the outcomes of manipulations.

The potential influence of a new science that invites participatory engagement in complex systems, whether physical, biological, social, corporate, or economic, is very great. I have touched on only a few of the issues that are coming within the purview of new developments that could link science more closely, and more responsibly, to major social issues.

12. See Mae-Wan Ho, 'Unravelling Gene Biotechnology', in *Soundings* 1, pp 77-98.

The Complexity of Creativity pp 139-151 | Cite as. Creativity, Complexity and Qualitative Economic Development. Authors. Authors and affiliations. Ã…ke E. Andersson. Chapter.Â The basic principles of work organization in the coming industrial society were clarified by Adam Smith in The Wealth of Nations, first published in 1776. And this book not only formulated the basic doctrine of the competitive economy and the constitutional rules needed for the smooth functioning of competition. To many the industrial revolution is perceived as a transformation from a society based on manual labor into a society with a production system based on machinery driven by manual based energy sources. However, this is a very minor aspect of Smithâ€™s vision. The core of his analysis is Defining this complex and multifaceted field, this book introduces a conceptual framework through which the various definitions of language and creativity can be explored. Divided into four parts, it covers: different aspects of language and creativity, including dialogue, metaphor and humour literary creativity, including narrative and poetry multimodal and multimedia creativity, in areas such as music, graffiti and the internet creativity in language teaching and learning. With over 30 chapters written by a group of leading academics from around the world, The Routledge Handbook of Language Creativity and Economic Development: We are living in the age of creativity.Â The effects of rising complexity calls for CEOs and their teams to lead with bold creativity, connect with customers in imaginative ways and design their operations for speed and flexibility to position their organizations for twenty-first century success. The Creativity Gap. A 2012 Adobe study on creativity shows 8 in 10 people feel that unlocking creativity is critical to economic growth and nearly two-thirds of respondents feel creativity is valuable to society, yet a striking minority â€“ only 1 in 4 people â€“ believe they are living up to their own creative potential. Can creativity be learn