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The Contribution of Systemic Thought to Critical Realism

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Abstract

Critical realism, especially as developed by Bhaskar, embodies at its heart systemic and holistic concepts such as totality, emergence, open systems, stratification, autopoiesis and holistic causality. These concepts have their own long history of development in disciplines such as systems thinking and cybernetics but, there is an absence in Bhaskar's writings, and that absence is a lack of any reference to the corresponding systems literature. The purpose of this paper is threefold: i) to demonstrate the extent of this correspondence; ii) to show that critical realism can benefit from an exposure to these other discourses; and iii) to show that systems thinking too can gain philosophically from critical realism.

Key words: autopoiesis, complexity theory, critical realism, cybernetics, emergence, holism, social systems theory, systems thinking

1. Introduction

Critical realism (CR) clearly embodies systemic and holistic themes at its very heart with concepts such as totality, holistic causality, emergence, open systems, autopoiesis, and levels of stratification. These concepts have their own history of development within the discipline known systems theory or systems thinking but there is almost no reference to this literature within Bhaskar's (or other critical realists') writings. I do not know whether this reflects a lack of familiarity with the literature or a desire to establish a new and autonomous discourse which is not seen as a part of something else. In any case, the links are in fact very clear and it is the purpose of this paper to draw them out.

I believe this is important to do for several reasons: first, it should be done for purely scholarly reasons. Systems thinking has a long history and its implicit contribution to critical realism should be made clear. Second, and more importantly, CR can gain from such an interchange. There has been much debate and clarification about these concepts within the systems literature which can aid their employment within CR, and there are further concepts and perspectives which CR could usefully employ. Third, systems thinking can, in its turn, gain from CR. Philosophically, it is still based on a schism between positivism and interpretivism which CR does much to dissolve.

The logic of the paper is that the first section will present a brief history of the development of systems thinking since the 1920's, not for its own sake but in order to explore the various theories, concepts and debates that are relevant to CR. The next two sections then discuss the use of systems concepts in Bhaskar's early (pre *Dialectics*) and later work.

2. The Development of Systems Thinking

Systems thinking or the systems approach[1] developed in its modern form with a burst of new ideas in a range of disciplines during the 1920s and 1930s although some of the underlying

[1] I shall use these terms interchangeably. The meaning of other related terms such as cybernetics, general systems theory (GST) or holism will be brought out in the text.

principles can be traced back to the Greeks, especially Aristotle[2]. Traditional disciplines that were involved include biology, psychology and even quantum physics, while new disciplines emerged, based on systemic ideas, such as ecology and cybernetics.
There was a major epistemological break within systems thinking during the 1970s in which a new stream of thought based on constructivism or phenomenology was initiated. This mirrored similar developments within the other social sciences which is obviously very much the concern of critical realism. This development is generally known as *soft* as opposed to *hard* systems thinking or sometimes *second-order* rather than *first-order* cybernetics.

2.1 Phase 1, hard systems thinking

The most fundamental idea of systems thinking is the anti-reductionist one that we cannot explain the behaviour of objects and entities purely in terms of the nature and constitution of their *parts* or *components*. Rather, the parts are related together in such a way that the whole has behaviours or, more generally, properties that are distinct from, and irreducible to, the properties of the parts. This is often expressed in the phrase, possibly due to Aristotle, that the whole is more than the sum of its parts. This is easily shown by examples: water has very different properties from its constituents oxygen and hydrogen; a plane can fly, its parts cannot; stereograms and *Magic Eye* pictures can generate 3-D images in a human brain; and a football crowd can produce a 'Mexican wave'.

This may seem obvious now, but in the early part of the 20th century it was totally against the prevailing worldview. Science had been incredibly successful over several hundred years based on the Cartesian reductionist view that the way to proceed was to successively split up entities into their component parts until ultimate components were reached, at which point ultimate explanations were possible. However, at this time Kuhnian-type problems were being experienced in all the major disciplines, even physics itself, and this led to the recognition of the importance of *wholes* over parts, or equally *form* over *substance*.

In biology, great progress had been made in understanding the parts of organisms, down to the level of their biochemistry, but this could not explain the complex behaviour of cells as a whole, nor could it explain how cells differentiated during the development of an organism. Two alternatives to reductionism emerged – vitalism and organicism. Vitalism[3] asserted that there must be some unknown or unobservable element or force that was possessed by living things, whilst organicism[4] held that the explanation was simply the organisation of the relationships and interaction of all the parts together. Early organicists actually used the term '*system*' and it was perhaps best articulated in Woodger's *Biological Principles*.[5]

Similar ideas were being developed in other disciplines. In psychology, the *Gestalt* school argued that perceptions and thoughts always occurred as wholes in themselves, which could not be broken up into parts.[6] This is often illustrated by perceptual illusions such as the young/old lady where we see one thing or the other but never both. Ecology was also picking up on ideas of relationships and wholeness from the organicist biologists. Haeckel[7] created

[2] Good sources for overviews of the history of systems are Capra, 1997, Checkland, 1981, Hayles, 1999, Heims, 1993. and there is an interesting and very detailed timeline at the American Society for Cybernetics, 2006.
[3] Driesch, 1908.
[4] Ritter, 1919.
[5] Woodger, 1929.
[6] Wertheimer and King 2005.
[7] Haeckel, 1866.

the term as ‘the science of relations between the organism and the surrounding outer world’, and von Uexküll[8] named the outer world *Umwelt* or ‘*environment*’ – another key systems concept.

Finally we can mention that atomic physics itself, the bastion of reductionism, also recognised wholeness at the very fundamental levels of subatomic particles which were not so much discrete particles but webs of interacting forces. As Heisenberg[9] put it: ‘ ..in modern physics the world is not divided into different groups of objects but rather into different groups of relationships … The world thus appears as a complicated tissue of events, in which connections of different kinds alternate or overlap or combine and thereby determine the texture of the whole.’

A second important realisation came out of quantum physics, again in opposition to the prevailing positivist view of science, which was the inevitable involvement of the *observer* in any observations or descriptions that we make of the world. Heisenberg’s uncertainty principle showed that the results we might get could not be simply reflections of the external world alone but were always in part due to the very act of observation. Again, as Heisenberg[10] put it, ‘Natural science does not simply describe and explain nature … it describes nature as exposed to our method of questioning’. As we shall see, it is very much one of the important planks of systems thinking that the observer must be recognised as part of the system.

The central systemic idea – that the characteristics and behaviour of entities depended on the structure of *relationships* between components rather than the properties of the components themselves – carries with it several other concepts – *emergence, hierarchy* (or stratification as Bhaskar tends to call it) and *boundaries*.

Emergence is certainly a key feature of Bhaskar’s critical realism which he has at times described as ‘synchronic emergent powers materialism’. Although the subject of much debate,[11] the basic idea of emergent powers or properties is clear. The emergent properties of an entity are properties possessed only by the entity as a whole, not by any of its components or the simple aggregation of the components (as for example in mass). Emergent properties result from the components and the particular structure of relationships between the components which constitute the entity. The examples presented above are all illustrations of emergent properties.

With emergence comes hierarchy. If we consider a system at a particular level it consists of components and relations. However, each component can itself be treated as a system and ‘opened up’ to reveal another set of components and relations. This process can in principle go on for an indefinite number of levels until we reach the bedrock of indissoluble forces. We can also go in the other direction from the initial system and see that it is only a component of a further hierarchy of wider systems. In fact the term hierarchy can be misleading – it is better described as a nesting of systems within systems much like Russian dolls. At each level systems, with their emergent properties, interact with each other governed by their structure of relationships generating a new level of system with its own emergent properties.

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[8] von Uexkull, 1909.
[9] Heisenberg, 1963. 107.
[10] Heisenberg, 1963, p. 75.
[11] Elder-Vass, 2005.

The third concept is that of boundary. If emergent properties are attributed to a particular entity in virtue of its components and relations we must be able we must be able to demarcate the system that has the properties from its environment. This may seem relatively clear when we are dealing with physically discrete objects that have a single clear boundary, but becomes much more contentious when dealing with complex systems that may be physically diffuse; that may consist of different types of components some of which may not actually be physical (e.g., information or ideas); and above all when we deal with social systems.[12]

The concepts covered so far may be considered structural in that they deal with the *structure* of systems as opposed to their *processes*. The distinction between these is time-relative but essentially the structure of a system is the components and relations between components that remain (relatively) constant over time. Process or dynamics is that which changes. The main researcher in this area, who is often seen as the founder of the systems movement, is Ludwig von Bertalanffy[13] (published in German in the 1940s)] with the concept of *open systems* and of *general systems theory (GST).*[14] Till that point science had generally concerned itself with systems that were closed to their environment. Within such systems the 2nd law of thermodynamics held and this suggested that entropy would always increase and the systems, including the whole universe, would eventually run down. However, this was clearly not the case with individual organisms or with evolution as a whole, both of which appeared to be anti-entropic. To resolve this dilemma, Bertalanffy proposed the concept of an open system which was in a state of dynamic (rather than static) equilibrium based on continual import from and export to the environment. Metabolism in the cell was one of the classic examples of this and the *self-regulation* of these processes was one of the key emergent properties.[15] Another concept developed at this time, based on principles of feedback, was that of *homeostasis*.[16]

Bertalanffy's second contribution was to try to establish a new, over-arching discipline known as general systems theory. This was based on the recognition that the systems concepts and principles we have described can be applied irrespective of the particular nature or substance of the systems concerned. It is therefore possible to study systems relationships and organisations in the abstract and then apply them, as with mathematics, to particular domains.

The next, and very significant, development happened during and after WWII with the development of an entirely new discipline – *cybernetics* – the science of communication and control[17]. The early cyberneticians, Weiner[18], von Neumann, Shannon[19] and McCulloch were mainly mathematicians and engineers who were interested in the ways in which systems, both mechanical and biological, regulated and controlled themselves in a largely automatic way. They recognised that the key to this was the concepts of *information* and *feedback*. Working initially on the design of self-controlling weapons the ideas soon spread into modelling the

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[12] Mingers, 2006, Ch. 4.
[13] von Bertalanffy, 1950, 1971.
[14] Although many of the ideas were foreshadowed by the Russian, Bogdanov 1980 (originally 1922). in his work on *tektology* which was not widely known at the time.
[15] These ideas formed the basis for Prigogene's 1984. work in the 1970s on dissipative structures for which he gained the Nobel prize.
[16] Cannon, 1939.
[17] The term *kybernetike* was used by Plato and Aristotle to mean the art of steering or governorship.
[18] Weiner, 1948.
[19] Shannon and Weaver, 1949.

functioning of the brain,[20] developing the first digital computers,[21] anthropology[22] and psychiatry.[23]

The most fundamental idea of cybernetics is that of *circular* (as opposed to linear) *causality*, more commonly known as *feedback*. This is a most ubiquitous phenomena in which a chain of causal connections is such that a change in one element eventually feeds back to either balance or reinforce the initial change. This had been known about practically for centuries. The Greek, Philon, designed an oil lamp which maintained its level of oil constant through a float, and Watt's steam engine governor was one of the most important inventions of the industrial revolution. The Watt's governor involved two heavy metal balls connected to the output axle of the steam engine. When the axle speeds up the balls move outward under centrifugal force; they are connected to the steam control so that the outward movement reduces the amount of steam which in turn reduces the speed of the axle. If the speed reduces, the balls move inwards with the opposite effect. This is a classic example of negative or balancing feedback which automatically maintains some variable at a constant level. Much of the regularity and constancy of the natural world is maintained by complex feedback loops such as this.

The opposite type of feedback also exists: positive or reinforcing feedback. Consider compound interest, a sum of money generates interest which is added to the money so that even more interest is produced in the next period. While negative feedback produces order and stability, positive feedback produces exponential growth or decay. The early cyberneticians were mainly interested in the way that negative feedback could produce apparently purposive or teleological behaviour without any form of conscious mental control,[24] although later Maruyama[25] focussed attention on positive feedback processes, in what he called 'second cybernetics'[26].

Systems concepts were also applied extensively in sociology, for example Parsons[27] whose work was criticised for being overly functionalist; Buckley[28] who emphasised the dynamic and processual aspects of systems; Luhmann[29] who produced a radical reworking of Parsons based on *autopoiesis*; and Habermas[30] whose work formed the basis for critical systems thinking.

The final development I will consider in the first phase of systems thinking is what became known as *system dynamics*. Jay Forrester, at MIT, was initially interested in applying the ideas of positive and negative feedback to investigating population dynamics – especially patterns of urban development.[31] He also applied the ideas to industrial supply networks[32] and perhaps the most famous analysis was the Club of Rome's report on the future of the world

[20] McCullough and Pitts, 1943.
[21] von Neumann, 1958.
[22] Bateson, 1936.
[23] Bateson, 1973.
[24] Rosenblueth, et al., 1943.
[25] Maruyama, 1963.
[26] Which is distinct from "second-order cybernetics" to be discussed later.
[27] Parsons, 1951.
[28] Buckley, 1967.
[29] Luhmann, 1995.
[30] Habermas, 1987.
[31] Forrester, 1969..
[32] Forrester, 1961.

economy called 'Limits to Growth'[33] which was one of the first to point out the effects of the world using up its natural resources.

However, from a critical realist perspective it is the later work of Sterman[34] and Senge[35] which is most relevant. They drew the distinction between the overt behaviour of the system of interest and the underlying, and often unobservable, pattern of causal relations that generated the behaviour. Their motto was that 'behaviour follows structure': put different people within the same structure and it is likely that the same behaviour will emerge. This is very similar to Bhaskar's distinction between the domain of actual events, and the domain of the real enduring mechanisms which generate them.[36] Senge also developed the concept of 'systems archetypes', that is, particular patterns of feedback loops that occur very often in the real-world and generate particular patterns of behaviour.

2.2 Phase 2, soft systems thinking

The work so far described was carried out within the prevailing positivist paradigm but, as in other disciplines, this was extensively critiqued during the 1970s and a new paradigm known as soft systems or second-order cybernetics emerged. Within cybernetics there had always been a recognition that observation was not wholly objective, but was to some extent dependent on the act of observation, or the observer. Heinz von Foerster and others at the Biological Computer Laboratory saw that in using cybernetic ideas to study the mind and the brain they were in fact also studying the process of observation itself.[37] This self-referentiality was referred to as the 'cybernetics of cybernetics'.[38]

The ideas were developed most coherently in the work of the biologists Maturana and Varela Maturana and Varela, 1980, Maturana and Varela, 1987, Mingers, 1995. who coined the term *autopoiesis* to described the circular, self-producing, organisation of living systems, a term that has been explicitly used by Bhaskar Mingers, 2004.. Maturana wanted to answer the most basic question: what distinguishes living systems from non-living systems? What is their essential property? He saw that you could not characterise a living system, for example an amoeba, in terms of purpose for it has no purpose except its continued existence, but you could in terms of what it *does*, what it produces. A living cell is a complex network of processes of chemical production that produces the very components which constitute the network in the first place. It produces itself. Non-living systems, which he termed *allopoietic*, produce something other than themselves, for instance, a chemical reaction converts some inputs into a different output. Autopoietic systems are organisationally closed but interactively open.

Maturana was also a neurophysiologist and had conducted empirical work on the perceptual systems of animals such as pigeons and frogs.[39] This work showed that there was not a one-to-one correspondence between the visual environment and the resultant neuronal activity. Perception could not be an internal picturing of the external world but was, rather, the result of internal patterns of correlation and association. Sensory stimuli did not determine but only triggered or selected subsequent states of nervous activity. The nervous system, too, is

[33] Meadows, et al., 1972.
[34] Sterman, 2000.
[35] Senge, 1990.
[36] Mingers, 2000b.
[37] Lettvin, et al., 1959, Von Foerster, 1984.
[38] Von Foerster, 1975.
[39] Maturana, 1968, Maturana, 1960.

organisationally closed – it is not open to the environment, our experiences are internally constructed although modulated through our interactions with the external world. This led to a strongly constructivist view of epistemology and ontology. The world that we experience, whether perceptually or linguistically, is a world that we construct; we can never have unmediated access to an external world:

> Indeed, everything said is said by an observer to another observer that could be him- or herself. [40]
> I am saying that all phenomena … are cognitive phenomena that arise in observing as the observer operates in language … Nothing precedes its distinction; existence in any domain, even the existence of the observer themselves, is constituted in the distinctions of the observer [41]

The second major source of interpretive thinking was within applied systems, specifically within engineering and management systems. Hard systems thinking had developed within engineering, for example in designing complex chemical plants. It had also developed within management as, for example, with Stafford Beer's management cybernetics[42] or Ackoff and Emery's 'purposeful systems'[43]. But a new paradigm was established with Checkland's development of soft systems methodology (SSM).[44]

On the basis of many practical projects in organisations, Checkland argued that social systems were intrinsically different to physical systems. One could not take the nature of a social system as given, from an external viewpoint, in the way that one could perhaps a machine or an organism. The essential difference is that the members of a social system, such as an organisation, would inevitable bestow their own meanings and senses on the system, and these had to be seen as equally valid ways of interpreting their reality. The purpose of SSM was, therefore, not to describe or design some objective system, but instead to articulate and explore the differing perceptions or Weltanschauungen held by participants within a problematic situation, and by doing so hopefully bring about an agreed improvement to the situation.

> {we} need to remind ourselves that we have no access to what the world *is*, to ontology, only to descriptions of the world, … that is to say, to epistemology. … Thus systems thinking is only an epistemology, a particular way of describing the world. It does not tell us what the world *is*. Hence, strictly speaking, we should never say of something in the world: 'It is a system', only: 'It may be described as a system'. … The important feature of paradigm II {soft systems} as compared with paradigm I {hard systems} is that *it transfers systemicity from the world to the process of enquiry into the world.* [45]

Checkland explicitly allied SSM to phenomenology and against positivism and he has never accepted the possibility of an excluded middle – namely critical realism.

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[40] Maturana, 1988, p. 27.
[41] Maturana, 1988, p. 79.
[42] Beer, 1966.
[43] Ackoff and Emery, 1972.
[44] Checkland, 1972, Checkland, 1981, Checkland and Scholes, 1990, Mingers, 2000a.
[45] Checkland, 1983, p. 671.

2.3 Critical systems thinking

Finally, I should mention that, like other social sciences, systems thinking has also developed a critical stream, drawing mainly on the work of Habermas[46] which recognised the role and limitations of both hard and soft systems thinking, and maintained that there was also a need for emancipatory systems thinking. And there has even been work drawing on postmodern perspectives and particularly Foucault's work.[47]

Recently consideration has been given to ethics and Mingers 2009. undertook a comparison between Habermas's discourse ethics Habermas, 1992. and the ethics implicit in critical realism.

2.4 Non-linear dynamical systems (complexity theory)

Complexity theory, also known as non-linear dynamical systems theory, developed during the 1970/80s in a range of sciences – biology, chemistry, mathematics and economics Kaufmann, 1995, Waldrop, 1992.. Traditionally, these hard sciences had assumed stability, equilibrium, linear change, cyclicality, robustness, and simple models generating simple behavior (and vice versa). Chaos and complexity are the results of a Kuhnian revolution that emphasises instability, far-from-equilibrium, sudden change, sensitivity to initial conditions and complex behavior from simple models (and vice versa) Mainzer, 1997, Lewin, 1992.. Two interesting questions are: to what extent do these insights apply to soft sciences and organizations Byrne, 1998, Cilliers, 2000.? And, to what extent can complexity theory be encompassed within traditional systems thinking?

Certainly there seems to be much evidence in our globalised world that many of these effects are indeed real at a social and economic level. However, with regard to the second question we would argue that all of the complexity effects can be generated within the traditional systems thinking framework as resulting from particular patterns of, especially positive, feedback loops and networks of interactions between large numbers of relatively simple units. For instance, Mosekilde and Laugesen[48] have shown that the Beer Game, a well-known feedback based management game, can display all the behaviour typical of complex systems.

3. Systemic Concepts in Bhaskar's Early Work

In considering systemic motifs in Bhaskar's work, I shall distinguish between the early material up to *Dialectic (DPF*),[49] where they are relatively implicit, and *Dialectic* and *Plato Etc*. *(P)*[50] where they become much more explicit but different terms are often used.

3.1 Systems, structures, mechanisms and emergence

A Realist Theory of Science (RTS)[51] begins in the Introduction by outlining the fundamental concepts from which the initial version of critical realism (CR) is built. The world is taken (on the basis of transcendental arguments) to consist of *structures* and *mechanisms* (or 'things', although that term has overly physicalist overtones for his later work) that have *powers* and *liabilities* to generate the events that actually occur. These structures are distinct from the events they generate. Events occur at a particular point in time, but the structures are

[46] Midgley, 1995, Mingers, 1992a, Flood and Jackson, 1991, Jackson, 1985 , Mingers, 1980.
[47] Brocklesby and Cummings, 1996, White, 1994, White and Taket, 1996.
[48] Mosekilde and Laugesen, 2007.
[49] Bhaskar, 1993.
[50] Bhaskar, 1994, Bhaskar, 1993.
[51] Bhaskar, 1978.

relatively enduring, exercising or not exercising their causal powers in interaction with each other.

The distinction is recognised between *closed* and *open systems* (and he does use the term 'system' here) where the former allow constant conjunctions of events, the Humean version of causality, but the latter do not. The claim is also made that both nature, and our knowledge of it, are *stratified* and *differentiated.* That is, that having investigated a structure at one level, e.g., chemical reactions, we can investigate the mechanisms underlying and causing this behaviour at a deeper level, e.g., chemical valency, and so on.

Emergent properties, which usually go along with ontological stratification, are not mentioned here, but are defended later in the book (p. 113). At this point Bhaskar is arguing against reductionism in science. He draws the distinction between the physical laws that may underlie the possible behaviours of, say, a machine, and the actual causal factors that lead to it being used in a particular way on a particular occasion. The latter cannot be explained purely in terms of the former, but come from higher level human or economic systems. He says:

'It follows from this that the operations of the higher level cannot be accounted for solely by the laws governing the lower-order level in which we might say the higher-order level is 'rooted' and from which we might say it was 'emergent'. … In short, emergence is an irreducible feature of our world'[52]

He further defends emergence, particularly in the case of society being reduced to the actions of individuals, or mind being produced to neurophysiology, in *The Possibility of Naturalism*[53] where he characterises his position as 'synchronic, emergent powers materialism. This will be taken up again in the discussion of holistic causation in Section 3. Elder-Vass offers an extended discussion of emergence in terns of CR's account of causation[54] and Archer's account of social structure.[55]

The other distinction introduced in the Introduction is between the intransitive and transitive domains of science. The former is the domain of objects of knowledge, such as structures and mechanisms, which are independent of humans while the latter is the domain of the human production of scientific knowledge.

These concepts can be translated, *prima facie*, almost directly into the language of systems thinking (see Table 1): systems forming wholes; a hierarchy of systems with emergent properties; structure and process; and systemic structure and interaction generating observed behaviour. However, when we look more closely we can identify a range of potential differences and distinctions that are worth discussion.

The first point is that Bhaskar is actually quite vague about terms such as structure, mechanism, thing, powers and tendencies. He does not really define them or explain what they might consist of, nor does he make it clear if they are actually synonyms or if there are differences between them. Bhaskar recognises this in the Postscript to *The Possibility of*

[52] Bhaskar, 1978, p. 113.
[53] Bhaskar, 1979, p. 97.
[54] Elder-Vass, 2005.
[55] Elder-Vass, 2007a.

Naturalism (PON)[56] where he responds to some critics. He says that he sees them as a network or family of terms (shades of Wittgenstein) that are interdependent but does not wish to define them more precisely so as to allow readers different ways in to the material.

RTS and PON	**DPF and P**	**Systems thinking**
structures, mechanisms, 'things'	totality	systems
	parts/wholes	parts/wholes
powers, liabilities, tendencies	holistic causality	emergent properties
	internal relations	relationships
open and closed systems	open systems	open and closed systems
stratified ontology	recursive embeddings	hierarchy or nesting of systems
emergent properties	emergent properties	emergent properties
intransitive and transitive domains		the observed and the observer
mechanisms generate events		structure generates behaviour or process
	tensed, rhythmic spatial processes	process, dynamics
	absence, negativity, real non-being	
	autopoiesis	autopoiesis
	transformative agency	soft systems, 2nd order cybernetics
		positive and negative feedback relations
		boundaries

Table 1 Comparison of Systems Concepts with Bhaskar's Main Works

He does, however, accept that he uses the term 'structure' to mean different things and tries to distinguish between structure and generative mechanism. 'It now seems to me to be better to use the term 'generative mechanism' to refer only to the causal powers of ways of acting of structured things.'[57] This seems to suggest that things have structures and, in virtue of that, possess causal powers which would be quite usual from a systems perspective. However the examples he gives do not accord with this. He suggests that a mechanism (his example being the market) may sustain several different structures, and that the same structure (his examples being nation-states or the family) may be reproduced by several mechanisms. First, it is not clear to me the difference between the market and a nation-state such that one is classified as a mechanism and the other as a structure. It also suggests a difference in level – mechanisms underlie and generate structures. But this becomes difficult when we consider that there are in fact many levels – does a structure at one level then become a mechanism for the structures of the next level up?

I would like to suggest that much of this confusion could be avoided if the systems terminology were adopted. 'System' would then be the general term for entities, of any type – e.g., physical, social, cognitive etc., that populate the intransitive domain. Systems consist of components and their relations which together are characterised as their structure. By virtue of that structure, systems have emergent properties or causal powers or tendencies to behave in certain ways. Systems are stratified, that is they form nested hierarchies. There are causal relations between systems at a particular level that generate events in the world; and there are causal relations between levels in that properties or causal powers of systems at one level,

[56] Bhaskar, 1979.
[57] Bhaskar, 1979, p. 170.

combined through their enduring relations, generate the emergent properties of the systems at the next level up.

One could still use the term generative mechanism, which does have valuable connotations, within the context of CR's retroductive methodology. Beginning with some particular events or observations that require explanation, we propose a particular (possibly unique) combination of systems, interacting together in certain ways, that would, if it existed, generate the observed events. We could give this ensemble the term generative mechanism. This is quite similar to Senge's archetypes,[58] mentioned above, which are particular sets of feedback relations that give rise to certain, common patterns of behaviour. An example is known as 'success to the successful': where two systems, e.g., universities, compete for a limited resource, e.g., good students. If university A gains a better reputation, for whatever reason, that starts an upward reinforcing feedback loop for A leading to more and more success, and a downward loop for B leading to less and less success even though both may have been similar to start with. These sort of processes can help explain the relatively wide dispersion of the 'new universities' (in the UK) that all started from scratch in the 1960s.

3.2 Positive and negative feedback

Discussion of feedback, or circular causal relations, leads me to point out that this concept is almost entirely missing from Bhaskar's work. It is not mentioned in any indexes, nor is it an entry in the voluminous *Dictionary of Critical Realism*.[59] There is a brief mention of homeostasis.[60] Yet, I would argue, it is fundamental in understanding the dynamic behaviour of real-world systems. This omission is partly explicable in that the early books, which we are currently considering, were more concerned with establishing the ontological and structural reality of mechanisms, or systems, rather than analysing their actual behaviour, There is more consideration given to processes in the later, dialectical, works which we will discuss below.

3.3 Processes and events

The next issue to discuss is the concept of event, which is central to Bhaskar's model. One of the primary distinctions is that between the enduring causal mechanisms and the temporal events that they generate, leading to the distinction between the domain of the Real and the domain of the Actual. Yet, the whole notion of an event is barely discussed at all even though it is the subject of significant debate within philosophy – see for example the *Stanford Encyclopaedia of Philosophy* entry.[61] For our purpose, I would suggest that an 'event' has two essential characteristics – that it is located at a particular point or interval in time and space rather than being an ongoing process or relationship, and that it involves some kind of change to a situation for if nothing changes there is no event.

Considering first the time element, the implication is that there must be a start, finish and some duration but the point is that these are entirely relative to the systems under consideration. Although we tend to think of events in relations to our human time frames, e.g., births, deaths and marriages, in principle they are not absolute but entirely relative. Cosmic events, such as the death of a star, may take millions of years while quantum events

[58] Senge, 1990.
[59] Hartwig, 2007.
[60] Bhaskar, 1986, 146.
[61] Casati and Varzi, 2002.

occur in nanoseconds. Even on a human scale, events may take a few seconds, a few months or even a few years. The point I want to make is that events are not given to us as things in themselves; rather they must be carved out of the ongoing flux of activities and occurrences according to some criteria or interest. And what turns up as events, as opposed to enduring tendencies, depends very much on the time scale that is adopted. If we observe the economy, the credit crunch may be seen as a single event if we take a 10-year perspective, but it may be seen as an enduring tendency generating events of its own in a weekly-perspective.

We must secondly consider the content of the event. We have said this must be a change, or else there would be no event, but a change in or of what? Surely there is nothing that can change other than the entities and structures (i.e., systems) that constitute the Real in the first place. There cannot be events as somehow ontologically distinct kinds of things. Thus events are nothing other than the changes that occur to and within entities and structures. These may be changes to an entity – i.e., it could gain or lose powers, or even disintegrate – or they may be interactions between entities that lead to certain outcomes or outputs. What is crucial, again, is the timeframe over which observations occur. The shorter the time frame, the more aspects of the situation that will be fixed or unchanging (structure in systems terms, enduring mechanisms in Bhaskar's); the longer the time frame the more that will become variable and changing (process in systems terms, events in Bhaskar's).

Bhaskar does get close to this conceptualisation in a brief section within *Scientific Realism and Human Emancipation* [62] where he says '…the study of *process* where structure meets events; that is in the study of the mode of becoming, bestaying and begoing of a structure or thing. … Process is not an ontological category apart from structure and event'. From a systems perspective, perhaps, ontologically there are only systems – process is the change to a system which can be sliced up into a series of events.

From a systems viewpoint this all points to the role of the observer. When conducting some sort of analysis or research, decisions have to be made about the level of the analysis (e.g., organisation, department or individual worker), the boundaries of the analysis (narrow or broad), and the timeframe. The particular decisions made, by the observer (i.e., the analyst or researcher) will determine what shows up as events to be explained rather than as explanatory generative mechanisms. Whilst Bhaskar recognises the general role of human activity in the production of knowledge through the transitive dimension of science, I would suggest that CR does not pay sufficient attention to the role of the actual scientist or researcher in a specific piece of research. It is the researcher(s) who, based on their own particular interests and pre-dispositions, carve out the object of scientific enquiry both by defining time frames, and the boundaries of the investigation (the domain of the Empirical) .

3.4 Boundaries

The concept of 'boundary' is itself a central one within systems thinking that is not dealt with by Bhaskar. Arguably, the concept of a 'system' existing within an 'environment' is the foundation for systems theory and yet what is it that separates a system from its environment – the system boundary. In fact, defining a system in terms of its components and their relations is effectively to delineate its boundary. Or, put the other way, in order to define a system it is necessary to define its boundary. Thus the drawing of a boundary is in fact the

[62] Bhaskar, 1986, p. 215.

most primitive systemic act that one can perform. However, as soon as we move away from very simple physical objects whose boundary is uncontentious (and that is often the metaphor that Bhaskar has in mind) the decision as to what constitutes the boundary, and thereby what is defined as the system, becomes complex and observer-dependent.

Even with essentially physical systems, there can be many different ways of conceptualising a system – consider for example a central heating system, or the human body. In these examples we can see that systemic thinking involves more than the simple recognition of particular objects. It begins with a particular phenomenon to be explained or purpose to be achieved. It then requires a degree of conceptualisation, rather than mere perception, to characterise an appropriate system in terms of components, relations and boundary. The boundary may in part have a material embodiment but generally it will simply represent a distinction or demarcation between that which has been selected as part of the system and that which is not. This does not mean that the boundary is purely arbitrary, or is wholly a construction of the observer. It rests on the components and relations that exist independently in the intransitive domain even though it is selected by the observer. This is demonstrated by the fact that the observer may *get it wrong*. Knowledge is always fallible and the real world will soon let us know if our choices of components, relations and boundaries do not in fact yield the appropriate behaviour. To quote a well-known management cybernetician, Stafford Beer,

> A system is not something given in nature, but something defined by intelligence. … We select, from an infinite number of relations between things, a set which, because of coherence and pattern and purpose, permits an interpretation of what otherwise might be a meaningless cavalcade of arbitrary events. It follows that the detection of system in the world outside ourselves is a subjective matter. Two people will not necessarily agree on the existence, or nature, or boundaries of any systems so detected. [63]

A detailed discussion of the difficulties of defining boundaries in different domains can be found in Mingers[64] The point for CR is that this is a very real issue in actual research projects.

4. Systemic Concepts in Dialectical Critical Realism

With the move to dialectical critical realism (DCR) there is a tremendous proliferation of terms and arguments. The main structure of DCR is known as MELD and has four aspects known as first moment, second edge, third level and fourth dimension as shown in Table 2.

1M, the first moment, is characterised in terms of non-identity, that is that things are not all the same, but involve many degrees of differentiation and stratification. 1M includes most of the distinctions from the early philosophy – transitive and intransitive, Real/Actual/Empirical; emergent powers, stratification, generative causality and mechanisms and events.

2E, the second edge, is characterised in terms of negativity and absence, that is that the world consists as much of things that are not present as things that are; or rather that things that are present, or do occur, only do so against a background of things that are not. This aspect

[63] Beer, 1966, p. 242-3.
[64] Mingers, 2006, Ch. 4.

brings in change and development for it is the need to fill an absence, or equivalently to absent an unwanted constraint, that brings about occurrences and events.

3L, the third level, brings in many more systemic constructs. It is, in fact, characterised as totality, that is holism and holistic causality. It brings in parts/wholes, inter-relations and inter-activity, recursive embeddings and reflexivity.

4D, the fourth dimension, is concerned with human agency, that is, emphasising that people are causative agents that can bring about change in a purposeful way.

	1M: First Moment	**2E: Second Edge**	**3L: Third Level**	**4D: Fourth Dimension**
Formal principle	non-identity (structure)	negativity (process)	totality (holism)	agency
motifs	critique of anthropism/epistemic fallacy transitive/intransitive real/actual/empirical	absence and ills axiology of freedom contradiction and constraint	holistic causality reflexivity	transformative praxis
World characterised by	intransitivity, stratification, transfactuality, emergence, control and change	real non-being negation process and transition: tensed, rhythmic, spatial processes priority of negative over positive	emergence wholes internal relations inter-activity	human agency intentionality autonomy
Critiques of	actualism: generally reductions to the here and now anthropism: seeing being in terms primarily of human being	ontological monovalence – a purely positive account of reality	ontological extensionalism – a denial of internal relations or causal necessity	disembodiment de-agentification – reification of social structure
Dialectics	superstructuration, stratification and emergence generative powers mechanisms and events structure and agency	critique transformative practice	totalisation centre-periphery part-whole recursive embedding	praxis hermeneutic struggle

Table 2 Overview of the MELD Categories

4.1 Holistic causality

Let us first consider holistic causality. Bhaskar makes clear what he means by this: it occurs when a *complex 'coheres'* (in our terms a system behaves) in such a way that,

i) the totality causally determines the elements and,
ii) the form and structure of the elements determines or co-determines the totality.

If the word 'determines' sounds overly deterministic, he accepts that the term should include other, weaker, relations such as conditioning, limiting, selecting, sustaining or enabling.[65] In considering this formulation, part ii) is quite unexceptional. It is the basic systemic notion of

[65] Bhaskar, 1993, p. 126.

emergent properties in which the behaviour and characteristics of the whole are generated by the structure of the parts and their relationships. However, part i) is much more controversial, even within systems thinking itself. For this suggests the in some way the whole, as a whole, influences or affects its parts, what is often called ‘downward causation’.

There are several potential problems here. The first is what we might call a logical concern over levels of organisations, or relations between parts and wholes (mereology). We have seen that systems form nested hierarchies in which the parts and their relations at one level give rise to the properties or behaviours of the whole at the next level up. This local-to-global causation is generally accepted except amongst strong reductionists. However, in what sense can a whole be said to interact with its own parts? Surely it only interacts with other systems at it own level? Cars interact with roads and other cars, not with their own engines.

The second problem is the philosophical one of microphysical reduction, i.e., that ultimately physics is seen as a closed and complete system of physical events.[66] With upward causation it is possible to argue that if the lower level generates the higher level, states at the lower level correspond to states at the higher level (supervenience) and could at least in principle be explained in terms of them.[67] However, downward causation would violate this principle and mean that there were genuinely necessary causal elements at levels beyond the physical.

A third potential problem is that holistic causality can easily be interpreted as a version of functionalism. Indeed, classical functionalism, if it existed, can be seen as a clear case of holistic causality – the parts of a system such as a social system actually come into being come into being because the functions they perform are necessary for the maintenance of the whole. This is discussed by Bhaskar.[68]

These concerns need to be dealt with and one way is through systems theory, in particular complexity theory (or non-linear dynamical systems), which has evolved a language extremely close to Bhaskar. Much of the debate about downward causation is at the level of the mind and its relations to the brain. Thompson and Varela,[69] for example, characterise emergence as follows:

> A network, N, of interrelated components exhibits an emergent process, E, with emergent properties, P, if and only if:
> 1. E is a global process that instantiates P and arises from the nonlinear dynamics, D, of the local interactions of N’s components.
> 2. E and P have a global-to-local (‘downward’) determinative influence on the dynamics D of the components of N
> 3. E and P are not exhaustively determined by the intrinsic properties of the components of N, that is they exhibit ‘relational holism’. [70]

The form of causation envisaged is one in which states of the whole system (called ‘global order parameters’) affect the possible states or behaviours of the components by constraining or affording particular paths or patterns of activity. So there is a ‘reciprocal causality’ in play in which the components interact directly and locally, generating and sustaining the

[66] Kim, 1998.
[67] Meyering, 2000.
[68] Bhaskar, 1986, p. 142.
[69] Thompson and Varela, 2001.
[70] Thompson and Varela, 2001, p. 420.

behaviour of the whole, while the whole sets the control parameters and boundary conditions for the components. Thompson and Varela[71] give general examples such as autopoiesis[72] and the immune system[73] as well as specific neurophysiological examples, such as epilepsy, where it is possible to show conscious thought affecting nervous activity. Equally, we can use the example of social systems within critical realism. Here, social structure (or system) is only instantiated through the activities of social agents, but at the same time the social structure of roles and practices conditions the activities that agents can undertake.[74]

This approach has the potential to deal with all three of the problems discussed above. If it can be demonstrated empirically, in some domain such as the mind or the social world, that downward causation does in fact occur then that refutes the first two objections. The issue of functionalist explanation is too complex to deal with here (see the entry in *Dictionary of Critical Realism*) but certainly Maturana and Varela have always maintained that their theory of autopoiesis is non-functionalist in that circular or reciprocal causality either happens, as a matter of fact, or it does not in which case the system disintegrates. They also accept the possibility of conflictual processes within a system.

4.2 Absence and negativity

One of the major developments from the early work to DCR was the incorporation of absence and negativity as one of the major presuppositions. Against the prevailing worldview that deals only with what positively occurs or exists, Bhaskar maintains that it is the absent or the negative which has priority for it is only against this that the positive stands out or happens. Bhaskar highlights four categories of absence: i) simple or ontological absence, i.e., that some thing or event that is expected does not occur or does not exist. Such absences can have causal effect and therefore 'exist' in the same way as other things. He calls them 'de-onts'. The instrument that is not to hand, the bill that is unpaid, or the appointment that is missed all have causal effects. ii) Absence as a verb, i.e, absenting something or negating something, e.g., draining water or removing dirt; or absenting an absence, e.g., removing a need or want by fulfilling it. iii) Developing from these are 'process-in-product' whereby a process (e.g., shopping) leads to an absence (e.g., money in the bank), and iv) product-in-process whereby an entity or structure (e.g., poverty, lack of money) exercises its powers in producing an absence (necessities of life).

This is interesting from a systems thinking point of view because it is *not* something that is generally discussed or considered in the modern literature and yet is clearly of great importance. In fact, its significance was recognised by some: it can be seen as the basis of cybernetic explanation as Bateson, one of the founders of cybernetics, observed:

> Causal explanation is usually positive. .. In contrast to this, cybernetic explanation is always negative. We consider what alternative possibilities could conceivably have occurred and then ask why were many of the alternatives not followed, so that the particular event was one of those few which could, in fact, occur. [75]

[71] Thompson and Varela, 2001.
[72] Maturana and Varela, 1980.
[73] Varela, et al., 1988.
[74] Archer, 2000, Mingers, 2004.
[75] Bateson, 1973, p. 375.

A similar idea is at the heart of Luhmann's[76] theory of social communication in which a message acts as a trigger or selector from among the many responses or replies that could be generated – it selects that which is presenced from among all the other absent possibilities. We can also see the importance of absence in the idea of control by feedback. The feedback system (e.g., a thermostat) is always trying to close a gap (absent an absence) between the desired state of the system and the actual state of the system.[77]

So, here could be a valuable contribution from CR to systems in terms of bringing to the forefront that which is generally absent, namely the concept of absence itself.

4.3 Autopoiesis

Autopoiesis means, literally systems that are *self-producing* or *self-constructing*. In traditional systems theory, systems were seen as open, transforming inputs into outputs. Biologists Maturana and Varela[78] developed the concept of autopoiesis to explain the special nature of living as opposed to non-living systems. Autopoietic systems are closed and self-referential – they do not primarily transform inputs into outputs, instead they transform *themselves into themselves*. The components of an autopoietic system enter into processes of production or construction to produce more of the same as necessary for the continuation of the system. The output of the system, that which it produces, is its own internal components, and the inputs it uses are again its own components. They are said to be organizationally closed but interactively open.[79] The paradigm example is a single-celled organism such as amoeba.

There have been several attempts to apply autopoiesis at levels above biology, in particular to suggest that social systems may be characterised as autopoietic,[80] but this is controversial and remains an open question.[81] Elder-Vass[82] has specifically contrasted Luhmann's approach with Bhaskar's and Archer's emergentism.

Bhaskar uses the term autopoiesis in several ways although never referring to the original literature. In *Scientific Realism and Human Emancipation* he characterises the whole process of knowledge production in the transitive domain as 'quasi-autopoietic':
'{Cognitive resources} comprise the transitive objects of knowledge; their transformation is the transitive process of knowledge production; and its product, knowledge, in turn supplies resources for further rounds of inquiry. This imparts to the cognitive process a quasi-autopoietic character' [83]

This is actually an interesting potential application of autopoiesis which has been little explored.

In DCR Bhaskar generalises this idea to describe the (re)production of the social system as a whole through human activity:

[76] Luhmann, 1990.
[77] Wilden, 1977.
[78] Maturana and Varela, 1980, Maturana and Varela, 1987.
[79] Mingers, 1995.
[80] Luhmann, 1982, Luhmann, 1986, Robb, 1989.
[81] Mingers, 1992b, Mingers, 2002.
[82] Elder-Vass, 2007b.
[83] Bhaskar, 1986, p. 54.

> The activity-dependence of social structures entails its auto-poietic (sic) character, viz. that it is itself a social product, that is to say, that in our substantive motivated productions, we not only produce, but we also reproduce or transform the very conditions of our productions. [84]

Again, this is a very appealing metaphor, but can we go beyond metaphor and claim that social systems *are*, ontologically, autopoietic?[85]

Finally, Bhaskar characterises emergence itself as being autopoietic: ‘In emergence, generally, new beings (entities, structures, totalities, concepts) are generated out of pre-existing material from which they could have been neither induced nor deduced. … This is matter as creative, autopoietic.’ Bhaskar, 1993, p. 49..

This is certainly a stimulating idea for debate within both CR and systems.

5. Conclusions

Bhaskar, in one of his discussions about absence, uses the example of books in a library and the many forms of absence that give them meaning. This paper, too, has been about absence – in this case the huge absence in Bhaskar’s work of any reference to the domain or literature of systems thinking despite it informing so many of his ideas. This is not said simply as a criticism of Bhaskar but rather as a recognition and invitation for further development.

The paper has hopefully served three purposes: i) to point out and justify the claim that many of the fundamental ideas of CR have already been developed within the disciplines of systems thinking and cybernetics and thereby open up this literature for followers of CR. ii) To try and demonstrate that potentially systems thinking has much to offer CR in terms of providing clearer articulations of the concepts, and also other concepts, such as circular causality through positive and negative feedback loops, that could be useful for CR. And, iii) to suggest that CR can also be beneficial for systems thinking partly by providing a more rigorous philosophical underpinning that systems lacks, and by its development of particular concepts such as absence/negativity.

At the least, I hope that this paper may open up dialogue and debate between the two disciplines.

[84] Bhaskar, 1993, p. 156.
[85] Mingers, 2002, Mingers, 2004.

References

Ackoff, R., and F. Emery 1972. *On Purposeful Systems*. London: Tavistock.

American Society for Cybernetics. "A timeline for the evolution of cybernetics." http://www.asc-cybernetics.org/foundations/timeline.htm.

Archer, M. 2000. *Being Human: The Problem of Agency*. Cambridge: Cambridge University Press.

Bateson, G. 1936. *Naven*. Stanford: Stanford University Press.

Bateson, G. 1973. *Steps to an Ecology of Mind*. Hertfordshire: Granada Publishing.

Beer, S. 1966. *Decision and Control*. London: Wiley.

Bhaskar, R. 1978. *A Realist Theory of Science*. Hemel Hempstead: Harvester.

Bhaskar, R. 1979. *The Possibility of Naturalism*. Sussex: Harvester Press.

Bhaskar, R. 1986. *Scientific Realism and Human Emancipation*. London: Verso.

Bhaskar, R. 1993. *Dialectic: the Pulse of Freedom*. London: Verso.

Bhaskar, R. 1994. *Plato Etc*. London: Verso.

Bogdanov, A. 1980 (originally 1922). *Essays in tektology: The general science of organization*. Seaside, CA: Intersystems Publications.

Brocklesby, J., and S. Cummings 1996. 'Foucault plays Habermas: an alternative philosophical underpinning for critical systems thinking.' *Journal of the Operational Research Society* 47, no. (6): 741-54.

Buckley, W. 1967. *Sociology and Modern Systems Theory*. Englewood Cliffs: Prentice Hall.

Byrne, D. 1998. *Complexity Theory and the Social Sciences*. London: Routledge.

Cannon, W. 1939. *The Wisdom of the Body*. New York: Norton.

Capra, F. 1997. *The Web of Life: a New Synthesis of Mind and Matter*. London: Flamingo.

Casati, R., and A. Varzi 2002. "Events." In *Stanford Encyclopedia of Philosophy*: Stanford University.

Checkland, P. 1972. 'Towards a systems-based methodology for real-world problem solving.' *Journal Systems Engineering* 3, no. (2): 87-116.

Checkland, P. 1981. *Systems Thinking, Systems Practice*. Chichester: Wiley.

Checkland, P. 1983. 'OR and the systems movement - mappings and conflicts.' *Journal of the Operational Research Society* 34, no. (8): 661-75.

Checkland, P., and J. Scholes 1990. *Soft Systems Methodology in Action*. Chichester: Wiley.

Cilliers, P. 2000. *Complexity and Postmodernism: Understanding Complex Systems*. London: Routledge.

Driesch, H. 1908. *The Science and Philosophy of the Organism*. London: Black.

Elder-Vass, D. 2005. 'Emergence and the realist account of cause.' *Journal for Critical Realism* 4, no. (2): 315-38.

Elder-Vass, D. 2007a. 'For emergence: Refining Archer's account of social structure.' *Journal for the Theory of Social Behaviour* 37, no. (1): 25-44.

Elder-Vass, Dave 2007b. 'Luhmann and emergentism: Competing paradigms for social systems theory?' *Philosophy of the Social Sciences* 37, no. (4): 408-32.

Flood, R., and M. Jackson, eds. 1991. *Critical Systems Thinking: Directed Readings*. Chichester: Wiley.

Forrester, J. 1961. *Industrial Dynamics*. Cambridge, MA: MIT Press.

Forrester, J. 1969. *Urban Dynamics*. Cambridge, MA: MIT Press.

Habermas, J. 1987. *The Theory of Communicative Action Vol. 2: Lifeworld and System: a Critique of Functionalist Reason*. Oxford: Polity Press.

Habermas, J. 1992. 'Discourse ethics, law and Sittlichkeit.' In *Autonomy and Solidarity : Interviews with Jürgen Habermas*, edited by P. Dews, 245-71. London: Verso.
Haeckel, E. 1866. *Generelle Morphologie der Organismen*. Berlin: Verlag.
Hartwig, M. 2007. *Dictionary of Critical Realism*. Abingdon: Routledge.
Hayles, N. K. 1999. 'The second wave of cybernetics: from reflexivity to self-organization.' In *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics*, edited by N. K. Hayles, 131-59. Chicago: University of Chicago Press.
Heims, S. 1993. *Constructing a Social Science for Postwar America: The Cybernetics Group 1946-1953*. Massachusetts: MIT Press.
Heisenberg, W. 1963. *Physics and Philosophy*. London: Allen and Unwin.
Jackson, M. 1985. 'Social systems theory and practice: the need for a critical approach.' *Int. Journal of General Systems* 10: 135-51.
Kaufmann, S. 1995. *At Home in the Universe: the search for the Laws of Complexity*. London: Penguin.
Kim, J. 1998. *Mind in a Physical World: An Essay on the Mind-Body Problem and Mental Causation*. Boston: MIT Press.
Lettvin, J., H. Maturana, W. McMulloch, and W. Pitts 1959. 'What the frog's eye tells the frog's brain.' *Proc. of the Institute for Radio Engineers* 47, no. (11): 1940-51.
Lewin, R. 1992. *Complexity: Life at the Edge of Chaos*. New York: Macmillan.
Luhmann, N. 1982. ' The world society as a social system.' *Int. Journal General Systems* 8: 131-38.
Luhmann, N. 1986. 'The autopoiesis of social systems.' In *Sociocybernetic Paradoxes*, edited by F. Geyer and J. van der Zouwen. London: SAGE Publications.
Luhmann, N. 1990. 'Meaning as sociology's basic concept.' In *Essays in Self-Reference*, edited by N. Luhmann. NY.: Columbia University Press.
Luhmann, N. 1995. *Social Systems*. Translated by J. Bednarz and D. Baecker. Stanford: Stanford University Press.
Mainzer, K. 1997. *Thinking in Complexity: The Complex Dynamics of Matter, Mind, and Mankind*. 3rd ed. Berlin: Springer.
Maruyama, M. 1963. 'The second cybernetics: Deviation-amplifying mutual causal processes.' *American Scientist* 51: 164-79.
Maturana, H., and F. Varela 1980. *Autopoiesis and Cognition: The Realization of the Living*. Dordrecht: Reidel.
Maturana, H., and F. Varela 1987. *The Tree of Knowledge*. Boston: Shambhala.
Maturana, H. 1988. ' Reality: the search for objectivity or the quest for a compelling argument.' *Irish Journal of Psychology* 9: 25-82.
Maturana, H., Lettvin, J., McCulloch, S. and Pitts, W. 1960. 'Anatomy and physiology of vision in the frog.' *Journal of General Physiology* 43: 129-75.
Maturana, H., Uribe, G. and Frenk, S. 1968. ' A biological theory of relativistic colour coding in the primate retina.' *Archiva de Biologia y Medicina Experimentales* Suplemento 1: 1-30.
McCullough, W., and W. Pitts 1943. 'A logical calculus of the ideas immanent in nervous activity.' *Bulletin of Mathematical Biophysics* 5: 115.
Meadows, D., D. Meadows, J. Randers, and W. Behrens 1972. *The Limits to Growth*. London: Pan.
Meyering, Theo C. 2000. 'Physicalism and Downward Causation in Psychology and the Special Sciences.' *Inquiry: An Interdisciplinary Journal of Philosophy* 43, no. (2): 181 - 202.

Midgley, G. 1995. 'What is this thing called Critical Systems Thinking?' In *Critical Issues in Systems Theory and Practice,* edited by K. Ellis, A. Gregory, B. Mears-Young and G. Ragsdell, 61-71. New York: Plenum Press.
Mingers, J. 1980. 'Towards an appropriate social theory for applied systems thinking: critical theory and soft systems methodology.' *Journal Applied Systems Analysis* 7, no. (April): 41-50.
Mingers, J. 1992a. 'Recent developments in critical management science.' *Journal of the Operational Research Society* 43, no. (1): 1-10.
Mingers, J. 1992b. 'The problems of social autopoiesis.' *Int. Journal Gen. Sys* 21, no. (2): 229-36.
Mingers, J. 1995. *Self-Producing Systems: Implications and Applications of Autopoiesis*. New York.: Plenum Press.
Mingers, J. 2000a. 'An idea ahead of its time: the history and development of soft systems methodology.' *Systemic Practice and Action Research* 13, no. (6): 733-56.
Mingers, J. 2000b. 'The contribution of critical realism as an underpinning philosophy for OR/MS and systems.' *Journal of the Operational Research Society* 51, no. (11): 1256-70.
Mingers, J. 2002. 'Can social systems be autopoietic? Assessing Luhmann's social theory.' *Sociological Review* 50, no. (2): 278-99.
Mingers, J. 2004. 'Can social systems be autopoietic? Bhaskar's and Giddens' social theories.' *Journal for the Theory of Social Behaviour* 34, no. (4): 403-26.
Mingers, J. 2006. *Realising Systems Thinking: Knowledge and Action in Management Science*. New York: Springer.
Mingers, J. 2009. 'Discourse ethics and critical realist ethics: An evaluation in the context of business.' *Journal of Critical Realism* 8, no. (2): 172-200.
Mosekilde, E., and L. Laugesen 2007. 'Nonlinear dynamic phenomena in the beer model.' *System Dynamics Review* 23, no. (2/3): 229-52.
Parsons, T. 1951. *The Social System*: Glencoe.
Prigogine, I., and I. Stengers 1984. *Order out of Chaos*. New York: Bantam.
Ritter, W. 1919. *The Unity of the Organism, or the Organismal Conception of Life*. Boston: Gorham Press.
Robb, F. 1989. ' The limits to human organisation: the emergence of autopoietic systems.' In *Operational Research and the Social Sciences*, edited by M. Jackson, P. Keys and S. Cropper, 247-51. New York: Plenum Press.
Rosenblueth, A., N. Weiner, and J. Bigelow 1943. 'Behaviour, purpose and teleology.' *Philosophy of Science* 10: 18-24.
Senge, P. 1990. *The Fifth Discipline: the Art and Practice of the Learning Organization*. London: Century Books.
Shannon, C., and W. Weaver 1949. *The Mathematical Theory of Communication*. Illinois: University of Illinois Press.
Sterman, J. 2000. *Business Dynamics: Systems Thinking and Modelling for a Complex World*. New York: McGraw-Hill.
Thompson, Evan, and Francisco J. Varela 2001. 'Radical embodiment: neural dynamics and consciousness.' *Trends in Cognitive Sciences* 5, no. (10): 418-25.
Varela, F., A. Coutinho, B. Dupire, and N. Vaz 1988. ' Cognitive networks: immune, neural, and otherwise.' In *Theoretical Immunology: SFI Series on the Science of Complexity,* edited by A. Perelson, 359-75. New Jersey: Addison Wesley.
von Bertalanffy, L. 1950. 'The theory of open systems in physics and biology.' *Science* 111: 23-29.
von Bertalanffy, L. 1971. *General Systems Theory*. London: Penguin.

Von Foerster, H. 1975. *The Cybernetics of Cybernetics*. Urbana: Biological Computer Laboratory, Illinois University.
Von Foerster, H. 1984. *Observing Systems*. Ca.: Intersystems Publications.
von Neumann, J. 1958. *The Computer and the Brain*. New Haven: Yale University Press.
von Uexkull, J. 1909. *Umwelt und Innenwelt der Tiere*. Berlin: Springer.
Waldrop, M. 1992. *Complexity: the Emerging Science at the Edge of Order and Chaos*. London: Viking.
Weiner, N. 1948. *Cybernetics: or Communication and Control in the Animal and the Machine*. Ca. Mass.: MIT Press.
Wertheimer, M., and D. King 2005. *Max Wertheimer and Gestalt Theory*. London: Transaction Publishers.
White, L. 1994. 'The death of the expert.' *Journal of the Operational Research Society* 45, no. (7): 733-48.
White, L., and A. Taket 1996. 'The end of theory?' *Omega, Int. Journal Mgmt. Sci.* 24, no. (1): 47-56.
Wilden, A. 1977. *System and Structure*. London: Tavistock.
Woodger, J. 1929. *Biological Principles: a Critical Study*. London: Keegan, Paul and Co.