Understanding Emergence:
A pragmatic interdisciplinary approach

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Abstract

Emergence is a concept which has been the subject of resurgent interest in recent years. The term is often used to describe the appearance of new macro-level properties or capabilities, which are not manifest in the individual micro-level components. Equally, it is associated with irreducibility of explanation, novelty and downward causation. Despite a long history, during which the concept has been adopted by different disciplines, there is little agreement on the real nature of emergence. This, I claim, is due to different philosophical and disciplinary perspectives as well as some lack of conceptual clarity. The aim of this thesis is not to resolve the extremely hard problem of what emergence is; rather it is to provide clearer insight into the nature of emergence. The thesis is therefore conceptual and analytical in nature.

The focus of the research is pragmatic investigation of the different perspectives, apparent disputes and real-world examples associated with emergence, in order to improve understanding of both the concept and instances of emergence. My thesis is that emergence is usefully conceptualised as fuzzy with three 'dimensions' – ontological, epistemological and complexity. This leads to the proposal of a typology of emergence which supports interdisciplinary discourse on the subject and a method of defining emergence in differing contexts. Both of these, it is argued, are vital to the development of shared meaning and the ability to engage in analytical discourse across the sphere of influence for emergence. The final proposal is a framework for investigation of real-world emergents which, while neutral to disciplinary or philosophical stances, enables exploration of the key of emergents. Together, the proposals provide a conceptual scaffold for understanding both the concept and instances of emergence. This claim is assessed through consideration of classical putative emergents and real learning communities.

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Part I

To aid clarity this thesis is divided into three parts. This part – Part I – sets the context of the research and consists of three chapters. Chapter 1 introduces the research problem, provides an overview of how it will be addressed within the thesis and summarises the significance of the research. This is followed, in Chapter 2, by an extensive review of literature on emergence. The objective of the review is to examine differing conceptualisations of emergence which arise from differing disciplinary and philosophical perspectives to ascertain: (i) what the major areas of conflicts are; (ii) why they arise; (iii) what might be deduced about the nature of emergence; and (iv) why understanding of real-world emergents continues to prove difficult. This critical analysis and synthesis is key to the thesis, forming the platform upon which the conceptual developments of the next part – Part II – are founded. Before proceeding to the conceptual development, the design of the research is presented in Chapter 3.

Part I is followed by parts II and III. Part II presents and discusses the conceptual development of the thesis. Part III is the final part of the thesis; here assessment of the conceptual developments of Part II is undertaken and the final summary of the research findings and conclusions is presented.

Chapter 1 Introduction

1.1 Research context and motivation

The term emergence is associated variously with phenomena that are complex (Holland 1998), novel (Broad 1925), unpredictable (Morgan 1923), irreducible (Bedau 1997), display downward causation (Campbell 1974) and are difficult to fully explain in terms of their component parts (Hempel and Oppenheim 1948). Given its focus, it is therefore perhaps unsurprising that despite a long history dating back to the turn of the last century, emergence is not fully understood in all its many forms (Kubik 2003, EmergeNET 2007)[1]; there is much debate regarding what constitutes emergence and whether particular phenomena are emergent or not. For example, to some, the only possible example of emergence is that of the mind from the physical brain (O'Conner and Wong 2006), to others the smell of ammonia, the markings on animal hides and life might all be emergent and to some, emergence simply does not exist (McLaughlin 1992)[2] or is merely an epiphenomenon (Pepper 1926). The concept itself has had a peppered history, with differing application domains and varying degrees of popularity. However, the significant resurgence of academic interest in emergence in recent years (Corning 2002, Clayton and Davies 2006) indicates the perceived value of the concept.

Two major research streams relating to emergence can be identified. Original interest in the concept dates back to the early British emergentist movement. While Mill (1843) was the first to introduce the concept, the main impetus began with Lewes (1875), eventually culminating with Broad (1925). What was of philosophical interest to Mill, Lewes, Broad and their compatriots is the apparent difficulty in explaining certain phenomena in terms of their component parts. For example, typical areas of interest were the relationship between the 'special sciences' – physical, chemistry, biology and psychology/social – and how the mind arises from the physical brain. At the heart of early emergentist thinking was the

1 EmergeNET is the new EPSRC network (Oct 2007) funded specifically to support "Unifying Investigation in Emergence, Emergent Phenomena and Complexity"

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apparent ontological irreducibility of these novel entities and hierarchies. Thus, these emergentists were concerned with philosophical understanding of the nature of reality. But as Hempel and Oppenheim (1948) point out, explanation is relative to current knowledge and conceptual models, questioning a purely ontological approach to emergence. The corollary of this is that claims to emergence can only be putative. More recently, philosophical interest has focussed on downward causation – how macro-level emergent phenomena affect their micro-level parts, a feature viewed by many as key to satisfactory explanation of the mind-body problem. However, the exact nature of emergence and indeed whether it exists or is merely an epiphenomenon with no additional explanatory value is still the subject of much philosophical debate.

The second stream of interest in emergence has developed over the last 30 years, where the term repeatedly arises in approaches designed to improve understanding of complex natural phenomena (Goldstein 1999, Corning 2002, Clayton and Davies 2006). In this context, emergence is associated with the formation of new macro-level phenomena which result from non-linear interaction of micro-level components. These systems of nonlinearly interacting components are known as complex systems. Examples of emergence within complex systems range from ant colonies (Gordon 1999), flocks, herds, and schools (Reynolds 1987) and learning systems (Davis and Simmt 2003) indicating the wide range of physical science, biological and social disciplines that are interested in emergence. Such complex phenomena are often considered explainable and predictable (in principle at least) through the non-linear relations of their component parts. In practice, given the often radically open nature of real-world complex systems, the causes and behaviour of such emergent phenomena remain poorly understood, leading to perceived unpredictability. Thus, emergence is characterised differently within the complex system community than within many philosophical accounts. Further, even amongst those interested in complex systems, there is much debate as to its true nature (Corning 2002). At the heart of complex systems interest in emergence is the vision espoused by Gell-Mann (1994) of seeking out generalisations based on the well-researched instances of emergence and using these understandings to make sense of less well understood complex phenomena.

Emergence is thus associated with hard problems of significant modern day interest, which in general continue to prove resistant to comprehensive scientific or philosophical understanding. Unfortunately, this inherent difficulty in understanding, explaining and manipulating emergence, I contend, is compounded by ongoing disagreement regarding the nature of emergence. Debate is a healthy and indeed fundamental part of improving understanding. However, the fact that the disagreement is both within and across disciplines and that we cannot even agree on whether a given phenomenon is emergent or not makes the sharing of insights across disciplinary boundaries difficult, although a potentially highly creative endeavour (Klein 1990). Despite this, we are beginning to see cross-fertilisation between philosophical and complex systems perspectives on emergence with Collier and Muller (1998) and Bedau (2002) drawing on complex systems perspectives to further philosophical discussion and Bar-Yam (2004) and Ryan (2006) attempting to capture philosophical notions within complex systems approaches. But, the conceptual foundation of this 'borrowing' is open to much debate given the disagreement that exists even within disciplines. Hence, I would argue, the generalisabilty of resulting insights must be questioned. Additionally, there is some doubt whether the different disciplines are even discussing the same concept. What I contend is, if progress is to be made in understanding emergence then we need to be able to clarify[3] what emergence is. If the nature of emergence could be better understood then it would arguably facilitate considerable insight into many of the real-world problems which arise in our increasingly complex world.

1.2 The research problem, questions and objectives

The brief introduction to emergence in the preceding section highlights the conflicts and gaps surrounding emergence. The general problem being investigated then is ***how to improve understanding of emergence, given the wide variety of perceptions and conflict regarding emergence.***

The many differing definitions and theses regarding emergence indicate a considerable, yet conflicting body of knowledge. Two paths to improve understanding present themselves. The research could drill down on one particular conceptualisation, refining it to provide deeper understanding within a particular domain. Alternatively, the research could attempt to consider emergence as a whole and understand why these differences in conceptualisations have arisen. While it might be easier to produce quantifiable results by adopting the former path, this circumvents the problem rather than truly addressing what emergence is. This leads to the principal research question of this thesis: ***Can a broad conceptualisation of emergence lead to increased understanding of emergence?*** What such a broad

[3] i.e. provide clearer insight into the nature of emergence, but not necessarily resolve.

conceptualisation might entail, how it might be developed and how it might be used to improve understanding of emergence is the crux of the matter addressed in this thesis.

The state of disarray in understanding the concept of emergence is such that there is no generally agreed definition of emergence let alone a unified theory of how emergence arises. Indeed, this lack of agreement is one of the few things agreed by current researchers into emergence (Cariani 1989, Goldstein 1999, Christen and Franklin 2002, Corning 2002, Kubik 2003, Boschetti et al. 2004, Clayton 2006a, O'Connor and Wong 2006, Ryan 2006). Nor, despite extensive consideration, is there agreement on whether specific examples are indeed emergent. For example, while the early British emergentists believed chemical or thermodynamic properties to be emergent on the physical atoms or compounds from which they arise, improved theoretical understanding through quantum mechanics in the former case and statistical mechanics in the latter has led some researchers to classify these properties as mere epiphenomena as they provide no additional explanatory power. However, the original promise of the new theories has failed to provide fully reducible explanations (Batterman 2005, Sklar 1999) and so their status as emergent is still much debated. There is also little consensus on the defining or 'essence'[4]/key characteristics of emergence – it has varyingly been associated with unpredictability, surprise, novelty, irreducibility, hierarchical levels of reality and the product of a complex system. Add to this the ongoing debate regarding whether emergence is ontological or epistemological in nature and it becomes clear that before a plausible broad conceptualisation can be developed, the nature of emergence, in all its various conceptualisations, needs to be considered. Thus, the first subquestion of the research is simply – ***what is emergence? (SQ-E)***

Developing a coherent conceptualisation of emergence will be critical to the success of this research – without coherence, sound analytical or scientific discourse will be impossible. This is of particular concern given the cross-disciplinary sphere of influence of emergence, as normal disciplinary conceptual or theoretical foundations cannot be relied upon (Wear 1999). The conflicting definitions and views described in the introductory section therefore

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[4] Essence here is not used in the strict Aristotelian sense where it implies "what it is to be" in a fundamental ontological sense. Rather, it simply captures the idea of a set of attributes that categorise an object as emergent. Categorisation is understood in this thesis as a psychological process and the attributes may be epistemological or ontological in nature. This usage of the terms essence and categorise should be assumed throughout the thesis.

appear highly problematic for the task at hand. However, instead of presenting irresolvable problems, these competing theories and conceptualisations may offer a means of exploring the concept in greater detail. This, after all, is at the heart of interdisciplinary approaches which are common within studies of complex systems (Klein 2004) and indeed is the rationale for EmergeNET (2007). Thus, rather than focussing on a narrow definition of emergence that necessarily alienates many views of the concept, exploration of how the various attributes, real-world examples and resulting contradictions give rise to our conceptualisations of emergence may, I argue, generate valuable insight into our understanding of the concept of emergence. By embracing these, I suggest, we might be able to make explicit assumptions and meanings to form a coherent conceptualisation. Thus, the second subquestion of the research is – ***how might the claimed key characteristics, real-world examples and contradictions surrounding emergence be used to improve understanding of the concept? (SQ-P)***

While improved understanding of the concept of emergence will aid clarity and interdisciplinary discourse on the subject, to be useful, I argue, it should also lead to improved understanding of real-world emergent phenomena – this is after all why both philosophical and complex systems interest in emergence have arisen. Thus, to ensure the research is well focussed and useful, the final subquestion of this research is – ***how might understanding of real-world emergent phenomena be improved? (SQ-RW)***

1.3 The research focus and approach

Given the diversity of disciplines which utilise the term emergence and the resulting variations in conceptualisations, if a broad conceptualisation that improves understanding is to be developed, then this suggests an interdisciplinary approach be adopted. According to Klein (1990, 2000), interdisciplinary discourse offers two principal lines of attack – 'borrowing', where concepts from one discipline are adopted by another discipline and 'problem solving', where different disciplinary skills are brought together to solve complex problems. While it could be argued that complexity scientists have engaged in 'borrowing' by adopting and adapting the philosophical concept of emergence, as I will contend, it is actually one core phenomenon that is at the heart of the various disciplinary discourses. It is thus the creative 'problem solving' form of interdisciplinary discourse that is of interest here. However, it varies from this general form in two ways. Firstly, the problem is a conceptual one rather than the real-world problems which are generally the subject of interdisciplinary discourse. Secondly, it is not simply a new method that is sought to resolve a complex problem – although arguably it is that too; rather, the quest is new conceptual development.

Interdisciplinarity is utilised in two different ways. Firstly, interdisciplinarity is achieved by adopting and contrasting insights arising, in the main, from complex systems, socio-technical systems, as well as philosophy – disciplines where there has been significant prior work on differing perspectives of emergence – to bring together differing concepts, epistemologies, terminologies and data – key facets of interdisciplinarity (OECD 1972). Secondly, the conceptual developments are designed to specifically support interdisciplinary discourse on emergence. These take the form of an epistemological framework that acts as bridge (Chettiparamb 2007), combining elements of abstraction of common understanding, translation and explicit disciplinary and philosophical stance related understanding. This bridging approach is necessary as shared understanding, language and methods, which are normally developed through disciplinary apprenticeship (Becher and Trowler 2001), cannot be relied upon within an interdisciplinary context (Wear 1999). This problem is clearly illustrated in the response to Corning's (2002) survey of researchers on an expert multi-disciplinary complexity forum, where a multitude of often inconsistent, if not incompatible, descriptions of emergence were in evidence. Thus, conceptual development must be designed to ensure that these potentially radically different interpretations of emergence are employed to give rise to a coherent discourse. Without coherence, I argue, a broad conceptualisation of emergence will do little to improve understanding.

As research question *SQ-P – how might the claimed key characteristics, real-world examples and contradictions surrounding emergence be used to improve understanding of the concept* – suggests, rather than avoiding the differences and conflicts, this research embraces them, using the conflicts and differences as a starting point for evolving understanding. This implies a degree of pragmatism must be adopted, evolving understanding by adopting and critically analysing the range of conceptualisations, their key characteristics, perceived conflicts and an extensive example set of putative real-world emergence. Basing the research on practicality, contextual examples and an acceptance that knowledge is evolving makes it pragmatic in the everyday sense of the word – it is not claimed that the research approach is that of pragmatism in the philosophical sense.

As the focus of the research is on developing an epistemological framework which improves understanding, the core activity is conceptual analysis, albeit of a pragmatic and interdisciplinary nature. The research concentrates on breaking down the differing conceptualisations of emergence to rebuild a broader but still coherent conceptualisation of emergence in order to provide a profitable way of understanding emergence. Profitable here may be thought of as plausible and potentially useful – i.e. the outputs provide a plausible and potentially useful way of understanding emergence and real-world emergents. Thus, the aim of improving understanding of emergence may be said to be satisfied if the outputs of this research enable profitable description of the concept of emergence and what constitutes real-world emergent phenomena, how they arise and how they behave – i.e. improved explanation of emergence and real-world emergents.

To summarise, the objective of this research is – ***to develop a broad conceptual framework which will act as an epistemological bridge, enabling researchers and practitioners from different disciplinary perspectives and philosophical stances to increase understanding of emergence within both interdisciplinary and disciplinary contexts (O).*** This is realised through development of a broad conceptualisation of emergence and related conceptual tools using pragmatic, interdisciplinary conceptual analysis.

1.4 Method, structure and contributions of the research

The research is divided into three parts – (I) setting the research context, (II) conceptual development and (III) assessment and conclusions. The rational for this choice and the overall focus of the research is considered in Chapter 3. The design is briefly summarised below.

Review of emergence

The research begins in Chapter 2 with extensive review and synthesis of existing approaches to emergence. Extensive coverage is critical to being able to capitalise on both the considerable extant knowledge base and the multiple perspectives of emergence. Thus the review process includes examining literature across disciplines interested in emergence as well as specific forums – publications or discussion forums – focussing on emergence. This should give confidence through the extent of coverage. This is supplemented by ongoing informal discourse with colleagues of differing disciplinary backgrounds. The review begins by briefly summarising the history of the concept of emergence. Then, to gain purchase on this difficult and complex phenomenon, a number of key classic examples of emergence that are often cited in the literature are briefly considered. Using these examples as discussion points, the principal approaches to emergence are then identified. This enables examination of why such different approaches arise, what causes the confusion and what can be concluded about the nature or 'essence' of emergence.

Three basic approaches to emergence are identified: (i) that it is a form of ontological novelty; (ii) that it is epistemological in nature, arising from a particular perspective, theory or state of knowledge; and (iii) that it is what complex systems produce. Analysis of the approaches focuses on exploring the contradictions and key characteristics relating to emergence – the key elements of *SQ-P, how might the claimed key characteristics, real-world examples and contradictions surrounding emergence be used to improve understanding of the concept?* This reveals that the approaches are frequently held to be incompatible, due in large measure to differing perceptions on the nature of understanding and the nature of reality, differing rationale for exploring phenomena and a failure to take into account the dynamic nature of emergence. There is also little agreement on the fundamental essence of emergence, with varying emphasis on irreducibility, predictability and causal powers as its key characteristics.

Conceptual development

Attention is turned in Part II to the major conceptual development of the thesis. A series of three conceptual proposals designed to improve understanding of emergence are presented and their plausibility and advantages discussed. The first stage is to introduce the broad conceptualisation of emergence in Chapter 4. This is achieved by drawing on the analysis of literature to consider what might reasonably be stated about the nature of emergence within an interdisciplinary perspective, thus beginning to address *SQ-E, what is emergence.* This leads to the central conceptual tenet of the research:

> ***Emergence may be profitably understood as a broad conceptualisation:***
>
> ***(i) of an inherently fuzzy concept***
>
> ***(ii) based around macro-level properties which are not manifest in individual micro-level components in isolation***
>
> ***(iii) which encompasses ontological, epistemological and complex dimensions***

Having established and discussed the broad conceptualisation, attention is then turned in Chapter 5 to how to utilise it to further elaborate the nature of emergence and to support interdisciplinary analysis regarding emergence. The realisation that a categorisation and elaboration of types of approaches to emergence has emerged from the literature review process leads to the proposal of:

> ***A multi-tiered typology of emergence based on the ontological, epistemological and complexity approaches to emergence and their key characteristics***

The multi-tiered typology, I will argue, provides a coherent way of linking locally consistent conceptualisations and hence supports interdisciplinary analysis regarding emergence. As this multi-tiered typology, further elaborates the nature of the emergence, it also further contributes to *SQ-E, what is emergence.*

Part II, and the conceptual development, ends in Chapter 6 by considering how to improve understanding of emergents within the context of the broad conceptualisation of emergence. Thus, attention is turned to *SQ-RW, how understanding of real-world emergent phenomena might be improved.* Drawing again on the findings on the literature review leads to the proposal of:

> ***An explanatory framework which develops a neutral but conceptually-relevant description of emergents, their causation and behaviour.***

The explanatory framework focuses on emergent phenomena rather than on conceptualisations of emergence, collecting neutral but conceptually relevant[5] information which can be used to develop useful descriptions of emergent phenomena. This 'grounding' in real-world phenomena as opposed to specific conceptualisations is critical as it not only facilitates analytical discourse regarding emergent phenomena, but it also provides a means of assessing the broad conceptualisation and multi-tiered typology.

Assessing the research

Analysis of the conceptual proposals is the subject of Part III of the thesis. It is achieved by applying the explanatory framework to classic putative examples of emergence and learning communities in Chapter 7. Inclusions of example emergents from a separate (secondary) learning community study, is important as these examples have not been used in the development of the conceptual proposals and therefore help to provide a degree of independent assessment. The descriptions generated are used to both assess the conceptual proposals and investigate emergent phenomena. As this analysis forms part of the pragmatic approach, it is undertaken with a view to evolving our knowledge regarding emergence and identifying and dismissing any inconsistencies in the conceptual proposals. In addition to providing detailed characterisations of the example emergents that clarify problematic areas,

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[5] Neutral but conceptually-relevant means that the description captures features and characteristics without requiring any particular conceptualisation of emergence to be adopted.

the analysis supports the inherent fuzziness and claimed conceptual dimensions of emergence, thus further supporting the profitability of the broad conceptualisation. The analysis also supports the claim that the multi-tiered typology can be used to describe and analytically discuss conceptualisations of emergence within an interdisciplinary context. Further, the profitability of the explanatory framework itself is supported by considering its success in developing explanatory descriptions of the example emergents which underpin the analysis of the broad conceptualisation and multi-tiered typology.

Having established not only the plausibility but also the potential usefulness of the conceptual proposals, Chapter 8 brings the research to a conclusion. After a brief recap of the research undertaken, the contributions of the research are discussed. This is followed by critical assessment of the success of the research and the research approach, where limitations and other potential approaches are considered. This leads to the conclusion that research has been successful, offering plausible and potentially useful insights into the very difficult problem of understanding emergence. The final step is then to discuss future work.

1.5 Significance of the research and intended audience

A key, and I will argue, innovative contribution of this research is the novel insight it provides into the nature of emergence. In particular, by showing that emergence might profitably be considered fuzzy, it offers a plausible explanation for why there have been such difficulties in developing a shared understanding of emergence. The research draws on Wittgenstein (1954) by embracing the fuzziness through the broad conceptualisation of emergence which acknowledges that emergence has ontological, epistemological and complexity dimensions, thus providing an epistemological bridge between conflicting perspectives and a platform for deeper exploration of emergence. In so doing, it extends the emerging realisation of Bedau (1997), O'Connor (2005) and Clayton (2006), amongst others, that complexity is at the core of emergence. While this fuzzy view is novel, it builds on Holland's (1998) observation regarding the problem of producing an ultimate definition of emergence, Roland et al's (1999) observation regarding debate on what should be included as emergence and Kubik's (2003) observation that current definitions of emergence seem to overlap in some unclear way. This view is important because it offers a reasonable explanation of the difficulties currently being encountered regarding the nature of emergence and suggests that some activities such as seeking an ultimate definition of emergence are likely to be unfruitful. Indeed, the realisation that a generalised explicit definition is not likely to be possible is a further useful contribution to knowledge. Further, this view of emergence supports the need to move beyond the ontological-epistemological debate regarding the nature of emergence, expanding it to also include how the concept developed, how differing views have arisen and how they are related.

Another key contribution is the support that the multi-tiered typology provides for coherent and, I will argue, plausible and potentially useful interdisciplinary conceptual analysis regarding emergence. The profitability lies in allowing us to coherently leverage different disciplinary knowledge, thus overcoming typical interdisciplinary issues such as lack of focus or common understanding that often lead to conceptual or scientific errors. It, therefore, offers a plausible way of moving beyond simple interdisciplinary borrowing of concepts to enabling different perspectives to be brought together to support analysis of the complex problem of what emergence is. The approach is novel as it employs an *idealised type* typology (Doty and Glick 1994) to support the analysis. So while it draws on the likes of Bedau (1997), Jones (2002), Silberstein (2002), Bar-Yam (2004), Fromm (2005) and Ellis (2006) in recognising the potential of typologies to aid understanding of emergence, it develops a very different kind of typology and applies it in an innovative way. In particular, rather than simply offering a method of categorising types of emergent, it facilitates sharing of meaning, generalisation regarding emergents, prediction of where new emergents might be found and extrapolation of characteristics. This ability to support sharing of meaning is another important contribution as lack of shared meaning has been particularly problematic within the discourse on emergence. It is not expected that a single unique meaning of emergence can or indeed should be developed. Rather, the contribution is a method of profitably facilitating shared meaning within a particular context.

The specific incorporation of the idea of an emergence system which represents the complex ontological and epistemological causal base in which emergents arise and exist is, I would suggest, an additional advantage. The idea that emergents have ontological or epistemological causes, or are the result of non-linear dynamics is not new. The contribution here is to bring to the surface the dimensions of the causal network, ensuring that all factors are considered rather than only those pertaining to a specific conceptualisation. This is important because it brings together complex systems and the varying philosophical considerations in a more structured way. It therefore extends recent moves to incorporate ontological causes and complexity thinking, to additionally include consideration of epistemological aspects. Inclusion of how we understand a phenomenon, I would suggest, is important given that the concept of emergence arose from perceived difficulties in explaining macro-level phenomenon.

Finally, the conceptual proposals – the broad conceptualisation, multi-tiered typology and explanatory framework – together form a conceptual scaffold for improving understanding of emergence. By this I mean that the conceptual proposals together offer a means of organising, analysing, synthesising, and evaluating emergent phenomena. The conceptual scaffolding and thus the ideas and outputs of this research are of particular interest to those involved in interdisciplinary research into emergence *per se* or into systems which display emergence. In particular, the reflective practice that the conceptual scaffolding supports not only aids consideration of emergent phenomena but also aids understanding of differing conceptualisations and how they are interrelated and hence has the potential to mediate between differing perspectives. As Klein (1990) suggests, it is by looking through these multiple lenses that researchers can open up a rich and fertile space for new ideas and insights. Given the current move towards interdisciplinary research (Creso 2007) and the increasing realisation that many of the technical and social systems in which we live are in fact complex, this suggests a wide field of relevance. Further, the conceptual scaffolding is of interest to practitioners as it offers a way of supporting development of shared meaning and understanding of real-world emergence systems. Thus, the implications of the set of conceptual tools developed in this thesis extend beyond the philosophical or scientific domain.

Chapter 2 Emergence

In Chapter 1, emergence is introduced as being variously associated with phenomena that are complex, novel, unpredictable, irreducible, difficult fully to explain, or exhibit downward causation. Despite this somewhat nebulous and at times inconsistent view of emergence, emergence is a field of significant interest as indicated by the considerable number of recent accounts of emergence ranging from informal discussion (e.g. Holland 1998, Kauffman 2000, Johnson 2001, Strogatz 2003) to formal definitions (e.g. Crutchfield 1994, Bedau 1997, Shalizi 2001, Bedau 2002, Kubik 2003).

One element which adds to the confusion surrounding emergence is the language which is used to discuss the concept. Terms are not consistently applied across disciplines. Before proceeding, two particular terminology-related issues are highlighted here and their preferred usage within this thesis clarified. Firstly, as Bedau (2002, p2) observes, "The proper application of the term "emergence" is controversial. Does it apply properly to properties, objects, behaviour, phenomena, laws, whole systems, something else?" Therefore, to aid clarity, the following terminology is adopted within this thesis:

> *Emergence* refers to the process which gives rise to *emergents.*
>
> *Emergents* are the results (products) of emergence and, as shall be discussed, may take the form of phenomena, properties, behaviour or rules.

Secondly, as the review will illustrate, emergence is varyingly described in terms of micro-macro, micro-global, lower-upper or lower-higher level relations. The particular terminology tends to depend on the research perspective – the former two tend to be used within complex systems while the latter two are more frequently used within philosophy. None are ideal. Micro-macro and micro-global may infer that the emergent is extensive to the whole system. This is problematic when trying to analyse systems where interrelated layers of emergence occur. For example, while social capital might emerge at the level of a community, it might not extend to the whole global community due to lack of connectivity. While using lower-higher or lower-upper terminology might avoid this confusion, these terms tend to infer an underlying ontological distinction which, as I shall illustrate, is open to debate. While I shall, in general, adopt the micro-macro terminology, lower-higher or lower-upper may still be used on occasion, especially when discussing particular perspectives which use the specified terminology.

Using the above terminology, this chapter explores the different approaches to emergence with the aim of identifying why different approaches developed and what the consequences of these differing views of emergence are for this research. Following the pragmatic and interdisciplinary strategies of this research, the review will concentrate on exploring the differing views of emergence, confusion and conflicts that have arisen with a view to identifying why these have arisen and what they might tell us about the nature of emergence. In particular, as well as (i) identifying major broad approaches to emergence, the review will (ii) identify particular conflicts which might be used to further explore the nature of emergence, (iii) assess what might be concluded about the nature or 'essence' of emergence and (iv) examine why understanding of real-world emergents continues to prove difficult. The review therefore is informed by *SQ-P - how might the claimed key characteristics, real-world examples and contradictions surrounding emergence be used to improve understanding of the concept?* To achieve this, extensive coverage of the considerable extant knowledge base and the different perspectives of emergence will be essential. This is achieved by examining literature across disciplines interested in emergence as well as specific forums – publications or discussion forums – focussing on emergence.

The chapter proceeds as follows. First, in section 2.1, a brief history of the concept is provided. Then in section 2.2, some examples of emergents from the extensive and varied literature on the concept are briefly introduced to set the context of subsequent discussions. Next, in section 2.3, three different broad approaches to emergences which arise in the literature are presented. This is followed in section 2.4 by an analysis and comparison of these approaches to consider why there are such different approaches, why confusion continues and what may be concluded regarding emergence and emergents. The chapter concludes in section 2.5 by summarising the findings of the chapter and identifying the next steps in the investigation of emergence.

2.1 History of emergence

Following on from the preceding introduction to differing views on emergence, a brief history of the concept of emergence, which is concerned with phenomena that are difficult to explain in terms of its component parts, is presented below. The history discusses, in broad terms, how the concept arose and key areas where the original concept has been adopted and developed; importantly though, it does not seek to either arrive at a definitive understanding of what emergence is or to provide a more general discussion of the development of scientific understanding/explanation in the last century. Detailed examination of specific approaches to emergence is left to section 2.3.

Interest in emergence as a concept can be traced back to the British emergentism movement of the turn of the last century (Corning 2002, Clayton 2006a). At the heart of this work by the British emergentists is the investigation of the relation between the so-called 'special sciences'[6] in an attempt to develop a materialism[7]-based philosophy of science (Stephan 1992). In broad terms, these emergentists were concerned with the extent to which we can understand and explain phenomena in terms of their component parts. In particular, the British emergentists were concerned with how, for example, chemical reactions need to be understood in terms of chemical level laws rather than lower-level physics laws and the ontological implications of these apparent distinctions.

While Mill (1843) was the first to introduce core concepts relating to emergence, the main impetus began with Lewes (1875) eventually culminating with Broad (1925) (McLaughlin 1992). Given the scientific paradigm of the time (Skyttner 1996), this problem of relationship between different scientific levels was original conceived in terms of causality. The philosopher Mill (1843), who did not directly employ the terms emergence or emergent, was primarily interested in scientific knowledge and the logic of induction. In particular, he considered different types of causation and their composition. This led him to propose "heteropathic laws" (Mill 1843, Book III, ChVI) where he claims "composition of causes" fails. By this he meant that certain causes can combine to give rise to a new set of laws which are not contained in the (vector) sum of the individual causes. The laws of chemical interaction he claimed are a prime example of this, leading him to attribute these "heteropapthic effects" to the separation of the 'special sciences'. The importance of Mill's work lies in the recognition that a new concept was required in order to describe the causal relations between phenomena at one level of the special sciences and the preceding level. As Corning (2002, p3) observes, Mill's work, therefore has shades of Aristotle's "The whole is something over and above its parts, and not just the sum of them all..." Building on Mill's

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[6] The special sciences were viewed as physics, chemistry, biology and psychology / social, with the physical sciences covering physics and chemistry.

[7] Materialism holds that everything is composed of matter alone. More recently the term physicalism is preferred – i.e. that everything is composed of physical things alone, in order to accommodate waves as well as particles.

work, Lewes (1875), who was primarily concerned with the nature of life and defence of British empiricism (McLaughlin 1992), introduced the term emergent to refer to the new phenomena that arise from Mill's heteropathic laws. Thus, in modern terms, an emergent phenomenon was one with a net-like causality.

Alexander (1920) expanded some of the ideas surrounding emergence. While McLaughlin (1992) notes that Alexander's work is full of inconsistencies, he identifies two important contributions to the development of the concept. Firstly, Alexander clearly rejected vitalism – i.e. that a living organism has a 'vital force' which is distinct from its physical composition – suggesting that apparently vitalistic behaviour of organisms can be fully 'explained' through the structure of the organism. However, the complex nature of the structure leads to the apparent vitalistic behaviour and new laws. Secondly, he also argued that if chemical-level behaviour can one day be explained in terms of physical-level laws then chemical behaviour is not emergent. This captures the fact that, to the British emergentists, being emergent was an intrinsic property and not just a result of current understanding.

Morgan (1923), an animal psychologist and behaviourist, built on the ideas of Mill and Lewes combining them with Darwin's ideas on evolution to discuss what he terms "emergent evolution". His thesis was that evolutionary processes give rise to new and unpredictable complex phenomena, which are wholly determined by their physical substrate – again, vitalism is clearly ruled out. This, Morgan claimed, eventually leads to the division between the sciences. The final major contribution to early British emergentism was the work of the philosopher Broad (1925) which according to Beckermann (1992a) provided the first proper explanation of an emergent property. Broad was concerned with emergentism and its distinction from what he termed 'mechanism'. What he was attempting to capture was a need to move away from the prevailing Newtonian paradigm which held that nature could be explained through linear cause and effect relating to basic physical components to an emergentist paradigm where while everything arises from the physical substrate, there are emergent laws which fundamentally "cannot be explained" (Broad 1925, p55).

In summary, British emergentism was then, in broad terms, concerned with developing a new philosophy of science, which would in today's terms be described as a physicalist but non-reductionist view of reality – i.e. while determined by underlying physical components, emergents cannot be explained through recourse to these physical components alone. The concept was introduced to describe higher-level phenomena which could not be explained in terms of the rules governing the lower-level behaviour. These emergents were considered to be novel and unpredictable. To these emergentists, emergence was ontological in nature – a fundamental feature of reality, which would not disappear as scientific understanding improved.

Interest in emergentism declined in the mid part of the last century, although there are conflicting views on why this occurred. According to McLaughlin (1992) while there were many criticisms of various aspects of the different writings on emergence, this demise was primarily because new scientific theories illustrated that some of the key higher-level properties that had aroused emergentists' interest in the concept, could in fact be explained though lower-level component parts (Corning 2002, Goldstein 1999). For example, it was shown that certain chemical properties could be derived from quantum mechanics and that thermodynamic properties such as temperature could be derived from statistical mechanical treatment of particles. This was particularly damning, because a key tenet of British emergentism was that there are some phenomena that cannot be explained in terms of their component parts. The scientific community, in the physical sciences at least, pursued a strong reductionist agenda as a result of these successes, seeking to find new theories that would provide ultimate explanations of real-world phenomena in terms of basic physical components.

Stephan (1992), however, contends that the demise of interest in emergentism occurred much later and was more attributable to the work of Hempel and Oppenheim (1948) which was concerned with the nature of scientific explanation and that of Nagel (1961) which was concerned with the structure of science. Stephen (1992, p26) holds these philosophers responsible, blaming them for developing "rather unambitious notion[s] of emergence" which resulted in a lack of interest in emergence from the philosophical community. Hempel and Oppenheim's work was viewed as particularly damning as it argued that emergent phenomena are merely the result of the particular choice of explanatory theories and our current level of knowledge. Emergence in their sense is an epistemological feature, which is quite distinct from the ontological emphasis of the early British emergentists.

Despite this lull in interest in the concept of emergence, some of the ideas associated with emergence continued to influence the development of thinking within a range of disciplines. For example, Sawyer (2005) argues that emergentism, along with organicism which stresses that biological organisms are best understood in terms of organisation rather than as composition of component parts, continued to influence thinking in psychology and sociology during this period. He cites General Systems Theory as a prime example. In broad terms, according to von Bertalanffy (1950) one of its leading founders, General Systems Theory is concerned with approaching problems or real-world phenomena from a holistic 'systems perspective' rather than breaking them down into their component parts. This focus on studying complex phenomena as a whole then marks a distinct break with traditional reductionist approaches to scientific understanding which were prominent within the physical sciences.

Fundamental to this general approach was the need to examine the system in question from multiple disciplinary perspectives within one overall systems framework. On one level, General Systems Theory, therefore, was again concerned with developing an integrated philosophy of science. However, unlike the early British Emergentists, the focus was on different disciplinary understanding and their meta-level similarities (Skyttner 1996) rather than on a hierarchical structure to scientific understanding. Further, while General Systems Theory shares with emergentism an interest in the wholes being more than the sums of the parts, unlike the work of the early British emergentists, it was concerned primarily with organisation and processes rather than the individual constituent parts and their relation to the whole. So on another level, General Systems Theory captured a move away from discourse on the nature of emergence and its role within a philosophy of science to attempts to develop theories pertaining to complex real-world behaviour, which needs to be addressed from multiple disciplinary perspectives. As Sawyer (2005) notes, while General Systems Theory and related theories such as cybernetics – which is an interdisciplinary field concerned with feedback and control mechanisms within systems – do use the term emergence to apply to the novel 'wholes' that develop in systems, these theories are not primarily theories of emergence. In particular, Goldstein (1999) argues for their omission because he claims they investigate simple systems in equilibrium, focusing on understanding the extant system and how it might be managed rather than how novel emergents arise, while Sawyer (2005) highlights their lack of interest in non-reducibility of the system and its behaviour/phenomena. General Systems Theory and related theories are, therefore, not discussed further in relation to emergence. However, as they are concerned with integrating understanding from different disciplines, they will be returned in Chapter 3 in relation to interdisciplinary understanding and the research design.

In the 1970s there was a minor resurgence of interest in emergence brought about by researchers interested in the mind-body problem which is concerned with how mental capabilities such as consciousness or memory arises out of the physical synapses and neurons of the brain[8]. Stephan (1992) cites the work of Sperry (1976), Bunge (1977) and Popper (1977) as being concerned with the kind of emergence discussed by early British emergentists. What was of particular interest here was not only how the apparently new higher-level properties associated with mind can arise but also how, or indeed whether, the macro-level mind can directly affect the individual physical components of the brain. This is frequently termed downward causation (Campbell 1974) and has become a major area of interest within the discourse on emergence. Sperry (1991 p222) positions his work as part of a move towards what he terms "emergent/holistic "top-down" thinking" in parallel with systems theory and related approaches in other fields. However, while emergence and the types of causal relations it entails have continued to play a role in the philosophy of mind into the 21st century with, for example, Chalmers (2006), Kim (1999, 2006a, 2006b), Murphy (2006), O'Connor (2000) and Silberstein (2002, 2006), the degree to which the mind is emergent upon the physical brain continues to be the central question.

Over the last 30 years, there has also been a significant interest in the concept of emergence from those investigating complex systems (Goldstein 1999, Corning 2002, Clayton 2006a) where the term is often used to describe the macro-level features which arise in nonlinear systems, where micro-level entities interact dynamically. These macro-level features often share the types of properties that the early British emergentists were interested in – e.g. complex causal factors, unpredictability, 'the wholes are more than the sums of the parts'. The complex systems movement arguably has arisen out of General Systems Theory and related theories and is concerned with novel, unpredictable phenomena which arise as the result of nonlinear interactions. Again the main ethos is that the 'wholes are more than the sums of the parts'. However, the key differentiator between complex systems type approaches and General Systems Theory is the emphasis on understanding complex phenomena in terms of self-organisation[9] and chaotic dynamics, focussing on creative non-equilibrium systems where novel emergent phenomena arise (Goldstein 1999). In particular, the development of Chaos theory in the 1970-1980s, which is concerned with the mathematics of non-linear dynamical systems, has been a key influence in this line of inquiry

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[8] The mind-body problem is briefly discussed below in section 2.2. For more extensive considerations see Kim (2006b).

[9] Self-organisation, where complex features arise from component dynamics alone rather than central direction is discussed in detail on page p51.

as it provides a theoretical underpinning for how apparently unpredictable and novel features can arise within nonlinear systems. This is exactly the kind of features that the early British Emergentists associated with emergence.

Goldstein (1999) links the adoption of the concept of emergence within the complex systems movement to the work of the Santa Fe Institute[10] on Complex Adaptive Systems. In particular, the work of Kauffman (1993), a biologist, Crutchfield (1994), a physicist and Holland (1998), a computer scientist, has been highly influential in the adoption of the concept of emergence by those interested in Complex Systems. These approaches are different from that of the early British emergentists in that they are based on a dynamical computational paradigm. As I will discuss in section 2.3, this means that the explanation of emergent macro-level features is viewed as explainable in terms of its micro-level component parts and their interactions. Again, what Kim (2006b) terms non-simply reductive physicalism rather than a holist approach is arguably at the core of this strand of complex systems approaches to emergence.

Despite this computational and arguably biological systems basis, interest in complex systems and emergence has spread beyond biology, physics and computing to, for example, business (Goldstein 2005) and social sciences (Sawyer 2005). Indeed, according to Sawyer, it is this computational basis, which as a result allows emergence to be explored virtually through computer simulations, that makes it potentially a powerful way for understanding complex emergent phenomena. However, as Sawyer points out new approaches may need to be developed to deal with social emergence.

The concept of emergence has, thus, had a long but chequered history. It was introduced in order to describe phenomena which appear inherently difficult to explain, marking a move away from both vitalist and reductive approaches to understanding the real-world. This – emergentism – has been varyingly viewed in terms of holism and non-simple reductionism. While some of the fluctuations of interest have been a result of evolving understanding and are inherent in the nature of scientific exploration, as is discussed in section 2.3, there are still fundamental differences in understanding of and approaches to emergence. Before proceeding to this discussion, some classic putative examples of emergence are introduced next.

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[10] Http://www.santafe.edu.

2.2 Classic putative examples of emergence

Ten examples of phenomena which might be considered emergent are briefly introduced below. These have been purposefully selected from the extensive literature on the subject to illustrate the different properties which are often associated with emergence as well as the wide range of interpretations of the concept of emergence itself. In particular, examples which illustrate unresolved conflicts between disciplinary perspectives or which are central to specific disciplinary interest in emergence are selected. These putative example emergents are followed by two illustrative examples which I claim are not intuitively emergent, although they have some similar properties to the ten putative emergents. These examples will be used throughout the thesis to compare existing approaches and to assess whether the thesis' conceptual developments are consistent with existing views and perceptions of what is and is not emergence.

(a) Mind

How the mind – thought, perception, will, emotion and imagination – arises from the physical components of the brain is a central question in both science and philosophy (e.g. Lewes 1875, Broad 1925, Alexander 1920, Sperry 1980, Searle et al. 1997, Chalmers 2006, Kim 2006b). The crux of the 'problem' lies in the fact that the mind appears to exist at a completely different 'level' from the physical neurons and synapses of the brain, and that, currently at least, it is impossible to explain the mind's working in terms of these physical components; completely different theories –psychological and physiological – are currently required to explain the workings of the mind and the brain.

It is this inability to explain fully the working of the mind and its relationship to the brain that leads it to be considered an emergent phenomenon. While the mind is clearly related to its physical form, its workings appear to a large degree to be independent of and therefore irreducible to the micro-level components. This leads to the potential for the 'higher level' mind to affect the physical brain. For example, results from cognitive behaviour therapy suggest that positive decisions and actions taken by the mind may lead to chemical changes in the physical brain.

(b) Life

The concept of emergence arises in the study of the history of life on earth – "now and again there is a sudden rapid passage to a totally new and more comprehensive type of order or organization, with quite new emergent properties, and involving quite new methods of further evolution." (Huxley and Huxley 1947, p120, cited in Corning 2002, p22) Like the mind-body problem, the qualitative novelty and multiple layers of organisation found in the biosphere have driven investigation into the concept of emergence (e.g. Lewes 1875, Morgan 1923, Rosen 1985, Kauffman 2000, Corning 2002). Biological cells are a good example of the difficulty in understanding of higher level phenomena which is commonly associated with emergence. While they are made up of chemical components, full understanding of the reproduction and functioning of a cell requires understanding of the macro 'cell level' processes of photosynthesis, respiration, protein synthesis and cell division; understanding of the micro-level chemical components does not provide complete understanding of the cell.

Life is also characterised by multiple levels of organisation – often viewed as an indicator of emergence. For example, cells combine to make organs which then form component parts of bodies. Within each level, the components provide a specific biological function and their behaviour is governed by a specific set of rules. For example, aerobic and anaerobic respiration are the set of metabolic reactions and processes which govern a cell's ability to convert biochemical energy from nutrients to support cell activities and then release resultant waste products. And at a higher level the body's endocrine system is an integrated system of smaller organs which, through feedback, controls the release of hormones which in turn control metabolism, growth, puberty and tissue function.

(c) Structure of the Universe

The development of the detailed structure observed in the Universe today from the initial big bang is another putative example of emergence. In the very early stages, the universe, which was expanding in both time and space, consisted of an extremely hot, dense plasma of energy and fundamental particles, whose actions were governed by the grand unified theory. Periods of expansion and cooling led to the formation of new particles and the separation of the grand unified force into gravity, strong, weak and electromagnetic forces – new components and rules of interaction arose. Over time, gravity took over as the dominant force leading to the gradual clumping and the seeding of galaxies and individual stars. Periods of star evolution eventually led to the formation of heavy elements and the core materials for planets, leading to the structure we observe today (Jantsch 1980, Peebles 1980, Riordan and Schramm 1991). Thus, radical novelty is a key feature here.

(d) Social Capital

Social capital is a good candidate for emergence within social systems. According to (Putnam 1995, p67) ""social capital" refers to features of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit". It does not lie within individuals; rather it "emerges from interaction and it depends on the characteristics of individuals and groups" (Daniel et al. 2003) . So, social capital is a global property of the interconnectedness of those involved. It, therefore, can be considered an emergent property of a social network.

(e) Thermodynamic properties

Thermodynamic properties such as temperature and pressure are often used to highlight the fact that novel 'macro-level' properties may arise from micro-level components (e.g. Hempel and Oppenheim 1948, Beckermann 1992b, Bar-Yam 2004) – another key component of emergence. For example, individual atoms do not possess temperature; rather these properties are a result of the global systems of particles which constitute a given substance. In this example, unlike that of the mind, micro-level theory – statistical mechanics – is able to 'explain' temperature in terms of the micro-level components which form an idealised gas, as temperature is equated to the kinetic energy of the average idealised gas particle within a substance. In solid state matter, the kinetic energy arises from vibrations of component atoms and for electromagnetic radiation it is the kinetic energy of the constituent photons. However, the concept of temperature does not make sense at an individual particle level.

(f) Smell of ammonia

The smell of ammonia is another property which is frequently discussed in reviews of emergence (e.g. Mill 1843, Broad 1925, Stephan 1992, Teller 1992, Christen and Franklin 2002, Ryan 2006). Ammonia – NH_3 – is a compound of nitrogen (N) and hydrogen (H), neither of which have the distinctive smell associated with ammonia. While Mill argued that its smell may be viewed as an emergent property, isolated ammonia does not possess the property of that distinctive smell, only its potential to realise it. The smell is only realised in the presence of nasal receptors. Thus, the smell of ammonia is an emergent property of ammonia in a particular environment – perceived emergents, in some instances at least, lie in the relation between entities and the environment and are therefore contextual.

(g) Patterns and stripes

Macro-level patterns which develop from animal hides to Bénard cells are also often viewed as examples of emergence. These patterns arise from the micro-level components as they interact over time. For example, Bénard cells are convection cells that appear spontaneously when liquids are heated from below. The heat causes individual cells of the liquid to rise, while gravity causes the cells to fall again. These two competing forces cause looped motion and a stable but dynamic macro-level structure to form.

A number of authors also cite global patterns which develop in cellular automata or agent-based simulations as examples of emergence (e.g. Bedau 2002, Wolfram 2002, Epstein 2006). For example, following on from the biological interest in emergence, the Artificial Life (Alife) community has spent considerable time exploring potential emergence in computer simulations, the classic Alife example being the gliders, blinkers, and guns generated in Conway's Game of Life (Resnick and Silverman 1996)[11]. In the Game of Life or other cellular automata, patterns which develop through individual cell interactions and global constraints are viewed as emergence. (Bedau 2002, Wolfram 2002, Bar-Yam 2004) Often these patterns are completely unexpected, illustrating that emergence is often associated with surprise.

(h) The function of a machine

The function of a machine which is built from constituent parts is another useful example in the emergence debate (e.g. Bedau 2002, Bar-Yam 2004). While the novel property – the capacity to perform a specific task – is not contained in any of the individual components of the machine, it is 'designed for', and therefore like the property of being a circle (subsection 2.2(j)), fully understood in terms of its component parts and their interrelation plus the task at hand.

Additionally, a machine may possess other properties which were not 'designed for'. For example, computers, originally designed for number crunching have become word processing and information retrieval tools – new higher level functionality has arisen over the course of time. The actual functionality lies in the properties of the machine and the context in which it is applied. The functionality was not 'designed for', although it may be argued that its potential was 'designed in', but not realised until the right circumstances arose. Whether every new application of a machine should be considered a new emergent is a subject of debate.

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[11] See (Resnick and Silverman 1996) for an interactive example of ALife emergence.

(i) The World Wide Web

The World Wide Web (Web)[12] is a global information system of interlinked hypertext documents, which are accessed via the Internet. The Web is more than a simple yet global information repository. It has a distinctive structure (Broder et al. 2000) where the connectivity of hypertext documents satisfies power law relations (Albert 1999, Broder et al. 2000) and constitutes a small world network (Adamic 1999). These global properties are properties of the complex network of interrelated documents which forms the Web and not of the individual documents. Further, with the advent of Web 2.0, the network of web links itself increasingly gives rise to collective information such as folksonomies (Shadbolt et al. 2006).

These global properties are both unplanned and unpredicted. While the Web is to a large extent engineered, human agency in the form of individual choices to link hypertext documents results in highly organic development and emergent properties (Berners-Lee et al. 2006).

(j) The property of a circle

Bedau (2002) proposes that the property of 'being a circle' should be considered emergent. As he points out, a circle consists of a collection of individual points which have no shape. Thus, the property 'circular' is a property of the 'whole' and not of the individual points – it is contained in the geometric relation between its points. This kind of global property is often referred to as a resultant or 'nominal' emergence. As is discussed further in section 2.3, some accounts of emergence exclude resultants as 'uninteresting' since they are fully defined and explained by the properties of their component parts.

Counter examples

(i) Two rowers in a boat

The new functionality described above begs the question, as to whether any new combination of events involving human participation may afford emergence. Consider for

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[12] The World Wide Web is not strictly a classic example of emergence as it clearly does not have a long history of association with emergence. However, it is included as it is arguably one of the most significant new examples of emergence.

example two people in a rowing boat. In order to get from one side of the lake to the other, they must work in tandem to achieve a specific task. While intuitively the rowers do not possess emergent functionality, they do work in tandem to perform a specific task, just like a machine. Exactly why this ability of the two rowers to cross the lake is not emergent will be discussed as the thesis progresses. However, the situation has similarities to the case of the weight of a bag of apples. If we add more apples, then the weight of the bag of apples will have changed. This change in weight is not considered emergent as it is perfectly explainable through simple addition (Morgan 1923). Similarly, I would suggest, the combined ability to cross the lake is perfectly explainable in terms of the individual ability of the rowers.

(ii) Diffraction pattern

Simple change is also generally not considered emergence. Consider for example a diffraction pattern which occurs when a beam of light encounters a slit. The pattern of the light before and after the obstacle is very different as the wave front changes from a continuous beam of light to a series of semi-circular lines. Such a pattern is in general not considered emergent as it is simply a rearrangement of macro-level features. For example, if I were to rearrange chess pieces on a board in a random manner, it would not qualify as an intuitive example of emergence. In the case of the beam of light, it is at the same 'level' before and after the diffraction event, it is perfectly understood and it can be predicted from the wave equation. However, if the beam of light were to be considered from the point of view of a stream of photons, then it may well be considered emergent as the wave form has radically different properties from the particle form.

In summary, as the preceding examples illustrate, a variety of properties are associated with emergence, including macro-level patterns and novelty, unpredictability, surprise, hierarchies and functionality. There is, however, still considerable disagreement regarding whether all or indeed any of these examples are emergent and which of the highlighted 'emergent properties' are necessary or sufficient conditions for emergence. Attention is turned in the next section to examination of the types of approaches to emergence that have developed.

2.3 Types of approaches to emergence

As might be expected with a concept on which it is currently proving difficult to form a consensus, attempts have already been made to compare and categorise approaches to emergence. For example, Stephan (1992) identifies different approaches by considering the properties on which they focus – 'nonadditivity', novelty, non-predictability and non-deducibility. Christen and Franklin (2002) on the other hand use a philosophical framework based on differing ontological and epistemological characteristics to analyse approaches to emergence. Clayton (2006a) examines emergence from a historical perspective and Goldstein (1999) compares the early historical work with more recent approaches developing within the field of complex systems.

Rather than using a predetermined framework, in this section, approaches to emergence are grouped according to their core rationale – that is the core features which motivate their authors to employ the concept of emergence. As Figure 2-1 below illustrates, this leads to three main types of approaches to emergence – ontological novelty, epistemological novelty and product of complex systems.

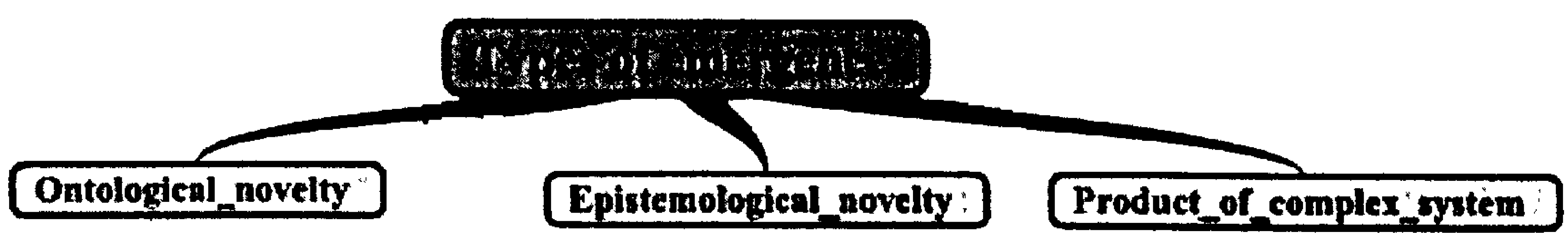

Figure 2-1: Overview of types of approaches to emergence

These approaches do not necessarily fall into mutually exclusive categories, but this particular grouping has been chosen as it helps clarify the associated 'mindset' of approaches, enabling constructive analysis of the range of thoughts surrounding the concept of emergence and highlighting important concepts, characteristics and conflicts in the process – a key part of the pragmatic research strategy introduced in Chapter 1. This choice is explained in detail in Chapter 3, subsection 3.2.1. The first two approaches – ontological (subsection 2.3.1) and epistemological (subsection 2.3.2) – are concerned with the philosophical nature of emergence. The third set of approaches (subsection 2.3.3) views emergence as the product of complex (non-linear) systems. Each of these broad types of approach are further analysed in turn to investigate what types of features are considered within each broad approach. This section concludes with a summary of findings.

2.3.1 Emergents as ontological novelty

Ontological approaches to emergence have arisen in the main from philosophical considerations surrounding the relationship between the mind and brain and between the 'special' sciences. Core to such approaches is the ultimate nature of the relation of the emergent to its constituent parts. The emergent may be simply novel macro-level properties or it may be considered to be novel macro-level-entities and rules. For each, the key drivers for consideration as emergence, claimed key characteristics and potential conflicts are discussed. The subsection ends with a brief summary of key points relating to emergence as ontological novelty.

Novel properties

The simplest ontological approach is based on *ontological novelty* where new properties – emergents – appear to lie at a different ontological level from their component parts (Mill 1843, Broad 1925, McLaughlin 1992, Bedau 1997, 2002, Silberstein and McGeever 1999, Kim 2000, 2006b). Inherent in these approaches is a distinction between micro-level components and a macro-level or 'whole' novelty. For example, to Alexander (1920, p45) "The emergence of a new quality from any level of existence means that at that level there comes into being a certain constellation or collocation of the motions belonging to that level, and this collocation possesses a new quality distinctive of the higher complex. The quality and the constellation to which it belongs are at once new and expressible without residue in terms of the processes proper to the level from which they emerge."

At the heart of the ontological novelty approach is the irreducibility[13] of the macro-level emergent to its component parts – "The emergent is unlike its components in so far as these are incommensurable, and it cannot be reduced to their sum or their difference". (Lewes 1875, p413) This captures the core idea that emergents cannot be understood or explained in terms of their component parts; the macro-level emergent requires macro-level description and understanding. For example, understanding of even the simplest life form requires cellular level concepts rather than purely chemical properties and interaction rules.

Ontological irreducibility is usually divided into two broad categories, commonly called *strong* and *weak* emergence. Strong emergents are ontologically distinct from their micro-level parts and cannot be 'understood' even in principle in terms of their component parts. Whereas weak emergents, as the name suggest, are less ontologically distinct, being reducible in principle but appearing in practice to be irreducible to their constituent parts.

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[13] Some of the early accounts of emergence discussed predictability or deducibility rather than irreducibility. Irreducibility, which is viewed as more rigorous and less ambiguous tends to be used now. See section 3.3.3 for discussion of relative merits.

(a) Strong Emergence

Strong emergence is most commonly associated with Broad who defines emergence as – "certain wholes, composed (say) of constituents *A, B,* and *C* in a relation *R* to each other; that all wholes composed of constituents of the same kind as *A, B,* and *C*, are capable of occurring in other kinds of complex where the relation is not of the same kind as *R*; and that the characteristic properties of the whole *R(A, B, C)* **cannot, even in theory,** be deduced from the most complete knowledge of the properties of *A*, *B*, and *C* in isolation or in other wholes which are not of the form *R(A, B, C)*." (Broad 1925, p61, emphasis added) This captures the idea that in strong emergence, emergents are at a fundamentally different ontological level and do not depend on the current state of theoretical knowledge. The most often quoted example of strong emergence is that of the mind from the physical brain.

The down side of this approach is that improved theoretical understanding may result in the downgrading of an emergent phenomenon to merely a resultant. As Hempel and Oppenheim suggest, this leads to the notion that identification of a phenomenon as strong emergence can only ever be provisional – "what is emergent with respect to theories available today may lose its emergent status tomorrow." (Hempel and Oppenheim 1948, p151)

The existence of strong emergence, while logically possible, is debatable (Bedau 1997, Epstein 2006). According to Chalmers (2006), the most likely example of strong emergence is that of the mind from the brain, while to Silberstein and McGeever (1999) the best evidence for ontological (strong) emergence is quantum mechanics. At the crux of the issue is how a macro-level property may be physically formed from micro-level entities but not reducible even in principle to them. To formalise such a relationship, the concept of supervenience[14] is often used. This captures the apparent causal independence of macro-level phenomena such as consciousness while retaining physical determination (Collier and Muller 1998) – i.e. it grounds the emergent's existence within the micro-level parts and their interrelations, but posits that the parts and their relationships do not fully describe nor explain the emergent. For example, Chalmers (2006) considers "strongly emergent phenomena as being systematically determined by low-level facts without being deducible

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[14] In supervenience, a macro-level property is determined by micro-level entities but its behaviour is not necessarily fully explainable by that of the micro-level entities. See McLaughlin and Bennett (2008) for further clarification of supervenience.

from those facts. In philosophical language, emergents are naturally but not logically supervenient on low-level facts."

Supervenience provides a conceptual foundation for strong emergence, avoiding vitalism – one of the main drivers of the British emergentist movement. But how supervenient relations, and hence emergents, arise in the first place is not the focus of philosophical discussions.

(b) Weak Emergence

Weak emergence is typically associated with Bedau (1997, 2002) who defines it as:

"Macrostate P of S with microdynamic D is weakly emergent iff P can be derived from D and S 's external conditions but only by simulation." (Bedau 1997)

Where S is a system composed out of "micro-level" parts, which may change over time; S has various "macro-level" states (macrostates) and D is a microdynamic which governs the time evolution of S's microstates.

This again captures the idea that weak emergence is a fundamental ontological property, although any specific classification of a phenomenon as weakly emergent may be subject to revision as understanding improves.

At first glance, Bedau's definition of weak emergence in terms of simulation appears odd[15]. He is attempting to capture the notion that, in theory at least, it is possible to derive weak emergent macro-level properties – the aggregate global behaviour – from micro-level components; in practice though, due to the complex nature of the micro-level interactions, this is not generally possible except by iteration and aggregation. This ability in principal to explain macro-level phenomena in terms of micro-level components makes weak and strong emergence distinct as Figure 2-2 below illustrates.

[15] In defence, he cites the lack of any other suitable concise wording to explain the required processes of iteration and aggregation.

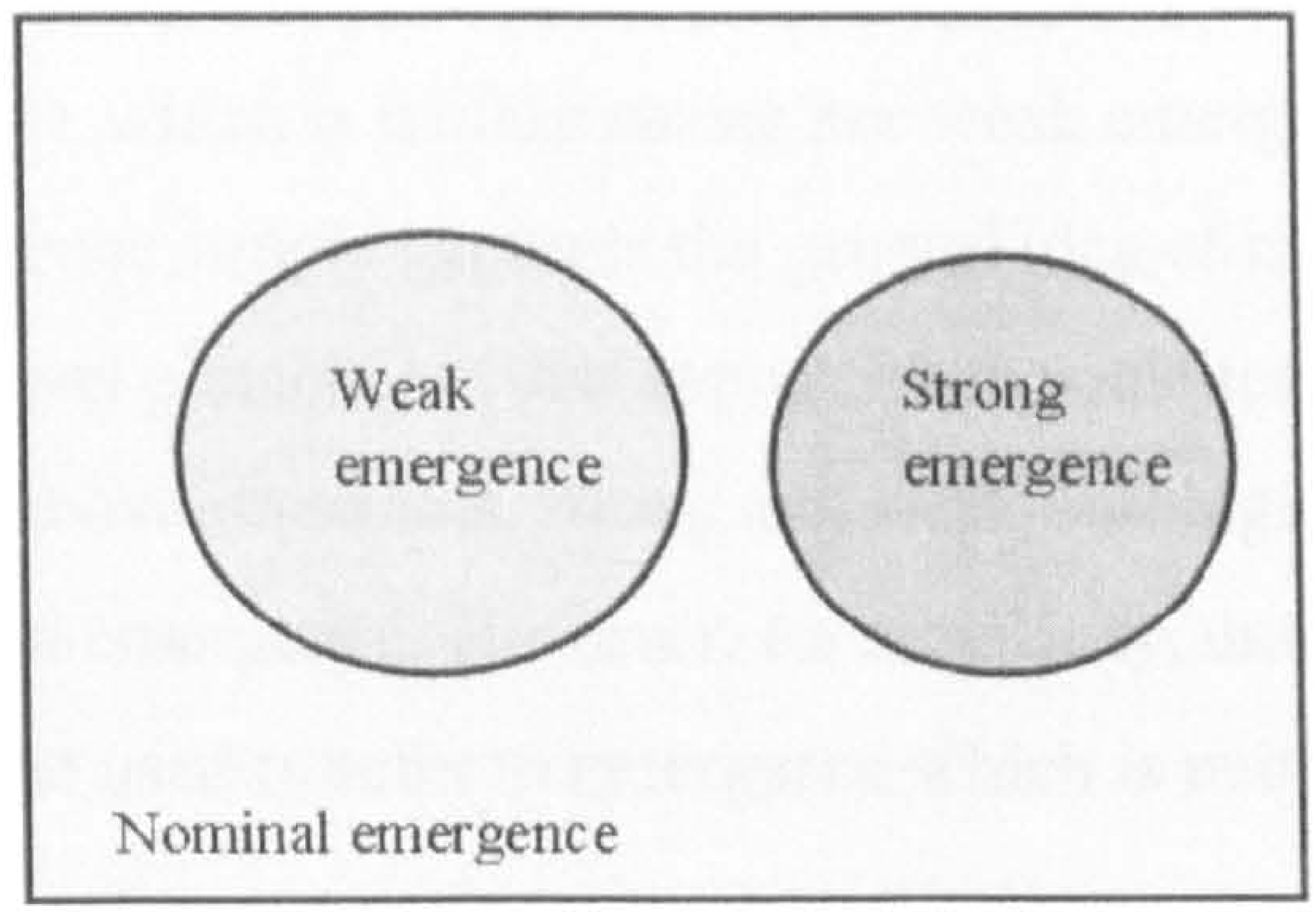

Figure 2-2: Relationship between Bedau's three types of emergence

Bedau claims that weak emergence is synonymous with emergence found within complex systems[16]. Typical examples of weak emergence are that of social capital and market equilibriums. For example, social capital, according to Bourdieu (1983, p249, cited in http://en.wikipedia.org/wiki/Social_capital), is "the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance and recognition". Thus, social capital is a network property – i.e. at a higher level – and as it depends on actual and potential resources, it is difficult to predict its exact nature or properties in advance – it is only derivable through its actual realisation.

Unlike strong emergence whose existence is questioned, weak emergence is generally accepted as existing. However, the usefulness of the concept has been questioned. As weak emergents are reducible in principle to micro-level components, it has been argued that they have no separate explanatory power making them merely epiphenomena and, therefore, not worthy of study as emergents (Kim 2000). However, if the emergents are reducible only in principle, in practice, weak emergents may indeed offer the only means of 'explaining' the macro-level phenomena. Additionally, as the subsequent discussion will illustrate, certain types of weak emergence may, indeed, causally affect the micro-level components. Thus, weak emergence should not be dismissed as a useless investigatory concept.

(c) Nominal Emergence

Some authors also include another form of emergence – nominal emergence (Baas 1994, Bedau 2002) which is "simply [the] notion of a macro property that is the kind of property

[16] Emergence within complex systems is discussed in section 2.3.3.

that cannot be a micro property". (Bedau 2002, p8) The property of being a circle, introduced in section 2.2(j), which is neither strong nor weak emergence, falls into this category. Nominal emergence simply captures the general idea of macro-level properties and includes all new macro-level phenomena that appear when constituent parts come together. Therefore, as Figure 2-2 above illustrates, strong and weak ontological emergence are distinct subsets of nominal emergence. However, for simplicity, unless otherwise specified nominal emergence will be used to refer to emergence which is neither weak nor strong.

Such nominal emergents are often dismissed as merely 'resultants' as their macro-level features are readily explainable in terms of their micro-level properties and interactions (Lewes 1875). For example, thermodynamic properties such a temperature of an ideal gas may be dismissed as mere resultants, as the individual gas particles which give rise to a global temperature are not coupled. But the concept of temperature does not make sense at the individual particle level. In this case at least, nominal emergence is a useful concept as it captures the micro-macro relationship which is inherent in the majority of approaches to emergence.

Novel entities and rules

As Heylighen (1989) observes – "an emergent whole at one level is merely a component of an emergent system at the next higher level." This leads to a variation on the ontological approach which considers not just novel macro-level properties but how novel entities and rules or theories appear at different ontological levels and their causal power. One sub-view is concerned with emergence of hierarchies, while others concentrate on the causal powers of these macro-level phenomena in terms of their affect on either other macro-level phenomena or their micro-level constituent parts. These three sub-views are discussed below.

(a) Hierarchies

Typical of the hierarchies view is Emmeche et al (1997, p84) to whom "emergence describes the passage between levels [of organisation]". The emergence of the biological level from chemical compounds captures this idea. Emmeche et al argue that emergence which gives rise to new levels is distinct from that which generates macro-level properties, describing these as primary and secondary emergence respectively[17]. 'Primary' emergence – levels – appear to occur when emergent macro-level properties become embedded, seeming to have independent existence and interaction with other macro-level entities – macro-level rules appear to be followed by the emergents. These rules are "laws (or in general: organizational and dynamical principles) that emerge from the regularities in collective behaviours of structures" (Baas and Emmeche 1997, section 8). As an example of such laws, Baas and Emmeche suggest "natural selection of genetically based self-reproducing entities". Contrary to its name, primary emergence, does not appear before secondary emergence, but gradually evolves over a period of time as the result of the interaction and constraints which results from emergent properties. Once a new level has emerged, the process of property emergence – Emmeche et al's 'secondary' emergence – may then begin again at this higher level; as Anderson (1972, p393) observes, "at each new level of complexity entirely new properties appear". This leads to the hierarchical view of emergent reality – "Emergence is characterised by hierarchical structures with different levels of order and descriptive languages (levels of phenomenology), plus a relational hierarchy at each level of the structural hierarchy". (Ellis 2006, p81)

This view of emergence is typical of researchers attempting to capture the perceived hierarchical relationship between the 'special sciences', distinguishing them as distinct, hierarchical ontological levels. Typical is Emmeche et al's (1997) identification of physical, biological, psychological and social levels. Ellis (2006) on the other hand identifies five levels of what he terms "emergent reality", noting that the distinction between levels is somewhat subjective. The variation lies in different approaches to distinction of levels. For example, Ellis takes a strong[18] approach – "One can't understand relations between the vast variety of objects at each higher level without using a hierarchical characterization of properties at that level" (Ellis 2006, p81). As do Collier and Muller (1998, p2) to whom "Something is hierarchically emergent if and only if its emergence implies the existence of a new level of existential dependence." While Fromm (2005) holds a much weaker view where it simply means multiple levels of organisation.

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[17] While Emmeche et al hold that emergence is ontological, they acknowledge their primary and secondary distinction is epistemological as ontological primacy can only ever be known in retrospect.

[18] Within the emergence literature, approaches are often referred to as 'strong' or 'weak', indicating the relative degree of irreducibility. This terminology is adopted here.

(b) Macro-level causal powers

The relationship of the causal interactions at the macro-level with micro-level entity rules is at the core of strong and weak approaches. Where these rules are irreducible to the rules governing the micro-level dynamics, the macro-level is said to have irreducible causal powers. However, even allowing for irreducibility, if some form of physical determinism such as supervenience is assumed (and vitalism avoided) then the rules which lead to the causal powers cannot be independent of the micro-level as they are still supervenient on the underlying level. For example, while sleeping tablets cause the mind to sleep, the chemicals within a sleeping tablet work on the physical brain.

The emergence of new rules at the macro-level does not necessarily imply strong emergence. As Bedau points out, even in simple systems such as the cellular automaton Conway's Game of Life, 'rules' develop at a higher level. For example, it is possible to alter the base cellular automaton conditions of the Game of Life to produce macro-level patterns which act like a finite state machine or even a universal constructor (Berlekamp et al. 1982). These rules are a direct consequence of lower level rules and structure[19]. As with ontological property emergence, the novel rules and hence levels are viewed as real ontological features and not just the result of current state of knowledge.

Macro-level causal powers may also occur in a weaker form where the macro-level does not possess clear rules, but the macro-level entity does appear to causally affect other macro-level phenomena.

(c) Downward causation

In addition to the causation within levels discussed in the previous subsection, some authors argue that an emergent has causal influence on its constituent parts. (Campbell 1974, O'Connor 1994, Emmeche et al. 2000, el Hani and Pereira 2000, Kim 2000, Bickhard 2000, Bedau 2002, Bar-Yam 2004, Chalmers 2006) This ontological approach arises from the view that if emergence is to have explanatory power – that is, if higher level emergents are better able to explain observed behaviour than their constituent parts – then the emergent should be capable of causally influencing processes at lower levels (Kim 2000).

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[19] By Bedau's definition, this is a form of weak emergence while Fromm (2005) suggests that this is actually strong emergence, although it runs counter to many definitions of strong emergence.

The term downward causation was introduced by Campbell (1974) to capture the idea that macro-level behaviour might have a causal effect on the micro-level components. According to Emmeche et al (2000), downward causation may be split into three categories – strong, medium and weak[20] – which are illustrated in Figure 2-3 below.

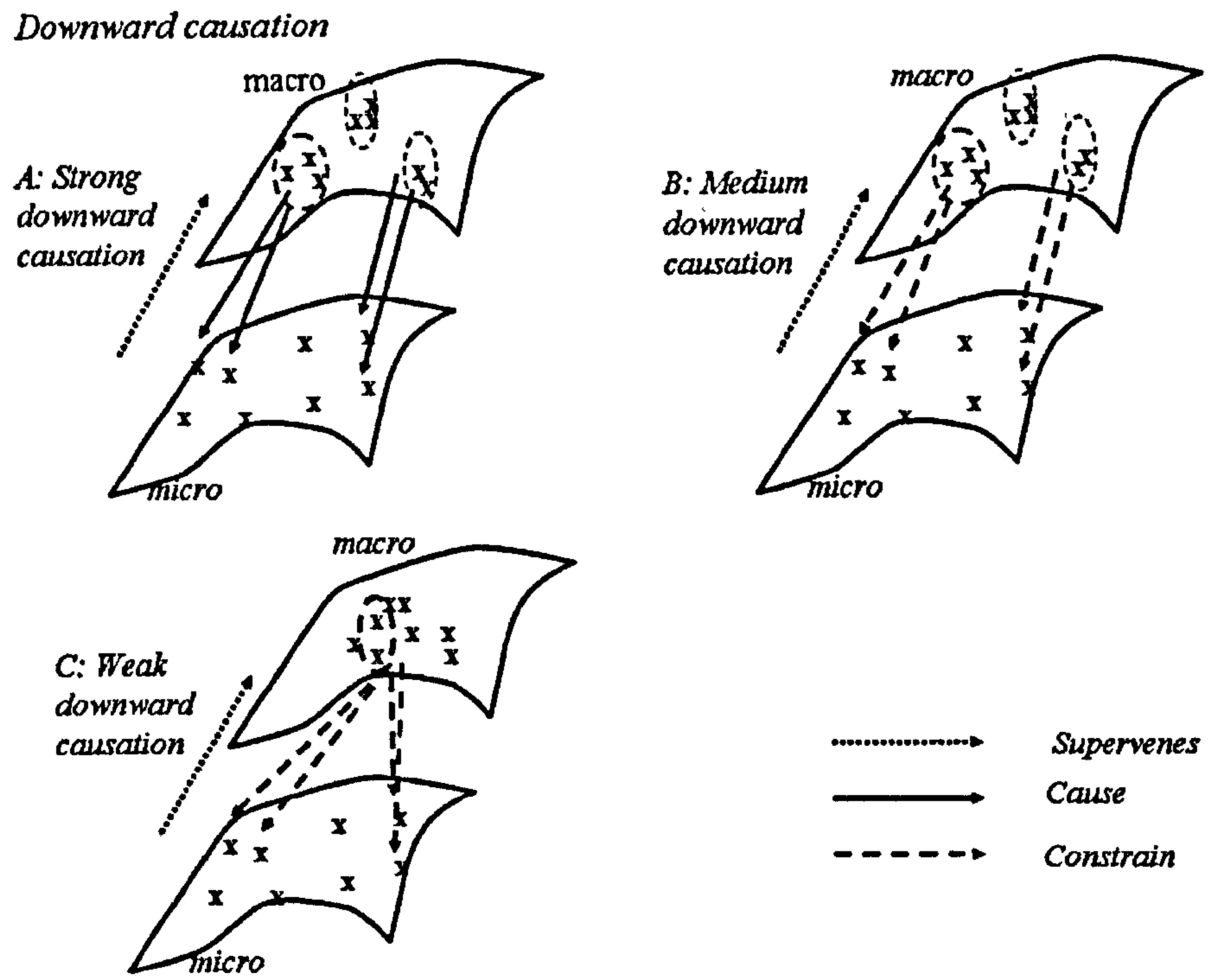

Figure 2-3: Three types of downward causation

Strong or 'irreducible downward causation' is illustrated in Figure 2-3 (A) and is typified in O'Connor's (1994, p97-98) description – "an emergent's casual influence is irreducible to that of the micro-properties on which it supervenes; bears its influence in a direct 'downward' fashion, in contrast to the operation of a simple structural macro-property, whose causal influence occurs via the activity of the micro-properties which constitute it." This strong version is most commonly used to describe the perceived effect of the mind on the brain. For example, a mental decision to run 'causes' a person's legs to start running through specific signals within the brain. It is important to note that it is the physical signals in the brain that are the claimed result of strong downward causation, not the leg movement.

Strong downward causation has been criticised on a number of fronts. Chalmers (2006) suggests that perceived irreducibility may just be a result of our current state of knowledge.

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[20] This should not be confused with strong and weak emergents.

Further, others, Kim in particular, question the fundamental logic associated with strong downward causation – "one cannot escape the feeling that there is something incoherent (perhaps, a form of causal circularity) about this variety of downward causation." (Kim 2000, p316) Kim splits his argument by distinguishing between synchronic and diachronic downward causation. Synchronic downward causation – where a macro-level emergent property P causes micro-level entity a_i to have property p_i, where a_i is part of the micro-level entities on which P is supervenient – is dismissed as circular and incapable of actual attainment when the act of attainment is considered at a given instant. Consider the following. By definition, a_i determines – along with other micro-level entities – P. But Kim suggests that when you consider how these properties are actually obtained at a given instant the argument collapses as the micro-level properties must exist first. Diachronic downward causation – where the macro-level property P is caused first and then exerts downward causal power on a_i – is also excluded by Kim as he argues that the necessary conditions which supervenience implies mean that the downward cause may be traced back to a basal micro-level cause and hence is not irreducible. Counter arguments have in turn been proffered to Kim's arguments, illustrating that there is considerable philosophical disagreement over the existence of strong downward causation.

In emergence which displays *medium downward causation* – Figure 2-3 (B) – "higher level entities are constraining conditions for the emergent activity of lower levels" (Emmeche et al. 2000, p25). This view does not admit direct causal interaction between related macro-level and micro-level components. Rather, the higher-level behaviour constrains lower-level possibilities. This captures Sperry's (1987) view that the mind governs rules and directs the physical components of the brain without interacting directly with these components.

In *weak downward causation*, the emergent macro-level consists of organisation or properties rather than ontologically novel entities – there are no recognisable macro-level rules or direct causal powers. According to Emmeche et al, the macro-level emergents arise out of attractor dynamics of the system[21]. This capture over time of system dynamics into attractor basins constrains the micro-level behaviour – Figure 2-3 (C). So an example of weak downward causation would be economic bubbles such as the UK property market bubble where, until very recently, a buoyant property market continually pushed up

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[21] Attractors are a feature of non-linear dynamical systems which display chaotic behaviour. See Glick (1987) for an overview of chaotic dynamics and attractors.

individual house prices or the fashion market where this year's fashion trend affects individuals' purchasing patterns.

While downward causation is generally associated with strong ontological emergence, Bedau (2002) expands the concept, associating the weaker versions of downward causation with weak ontological emergence. Through analysis of the emergent computational patterns in Conway's Game of Life, he argues that macro-level patterns such as gliders shooting from guns cause micro-level cells in the automaton to become alive – i.e. macro-level patterns affect micro-level behaviour. Both medium and weak downward causation obey causal fundamentalism where the macro-level causal powers arise either directly or through supervenience from the micro-level (Bedau 2002) and frequently the term weak downward causation is applied to both.

Downward causation again has many issues. Emmeche et al (2000) provide a good overview of the varieties of downward causation and problems associated with each.

Summary of emergence as ontological novelty

Figure 2-4 below summarises the important features of ontological approaches to emergence identified in this subsection. The top level of the figure identifies the broad approach to emergence. The second level nodes identify the main subapproaches within this broad approach, which are differentiated by interest in different macro-level phenomena. The third level provides further differentiation of approaches where there are several differing interests in the key focus of emergence. Below this tree structure, the key characteristic associated with the given sub-approach to emergence and its subtypes are identified. For ease of display, where a number of sub-approaches share interest in the same key characteristic, the key characteristic and its subtypes are displayed below the centre of the group of subtypes. So in Figure 2-4, the 'Hierarchies', 'Macro_entity_causal_power' and 'Downward_causation' sub-approaches all share interest in 'Irreducibility'. This convention will be used throughout the thesis.

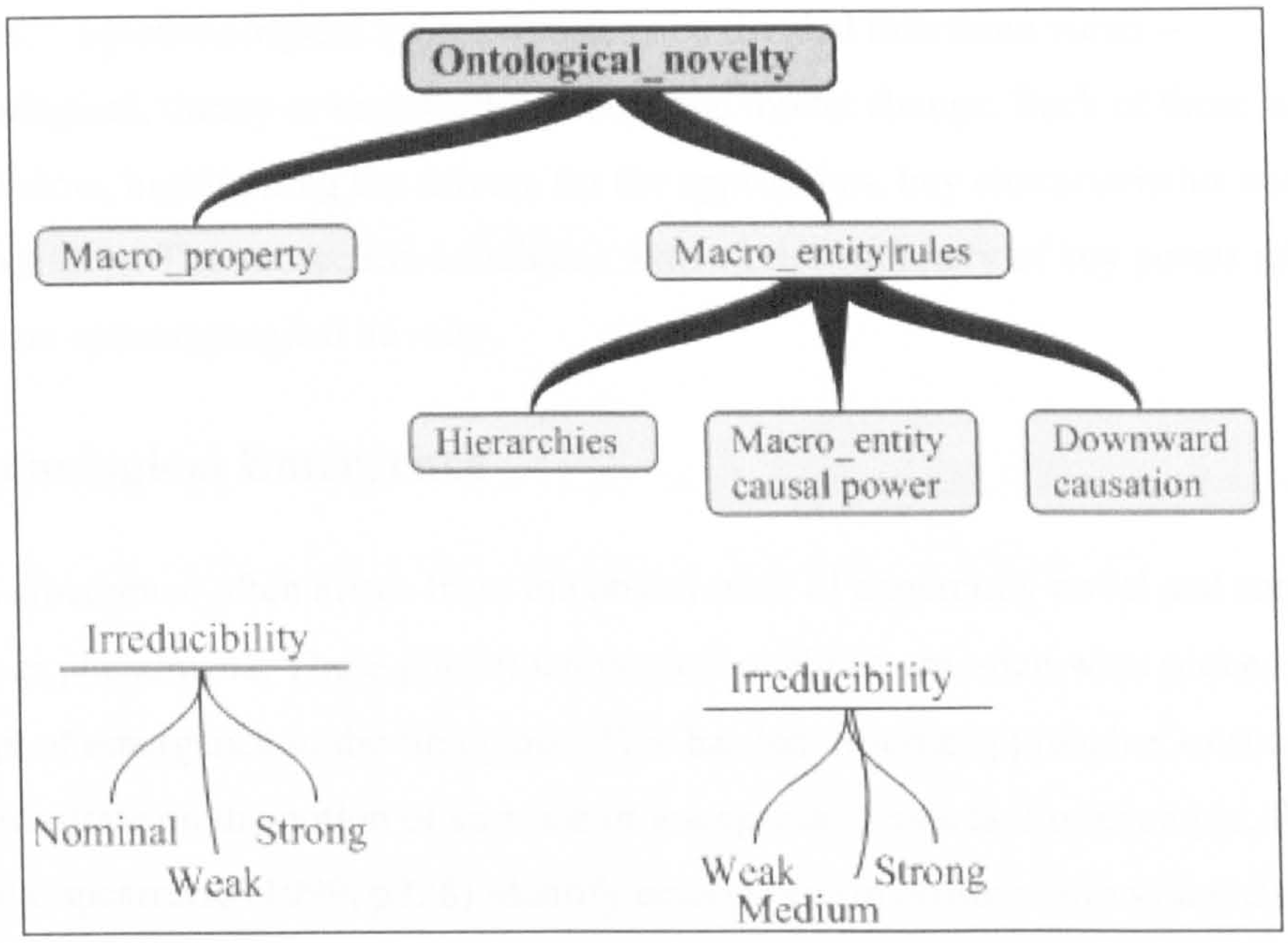

Figure 2-4: Summary of ontological approaches to emergence

The ontological approaches summarised in Figure 2-4 are characterised by their explicit analysis of the ultimate nature of emergence and its causal powers. The approaches are based on the degree of irreducibility of macro-level features – i.e. properties, rules, entities – and their position in a hierarchy or causal powers, be it macro-level or downward causation. But as the preceding discussions illustrate, there is considerable debate regarding what degree of irreducibility is appropriate or indeed plausible for emergents. The rationale for ontological novelty approaches is that apparently novel macro-level phenomena arise for fundamentally ontological reasons. Thus, at their core, these approaches claim to be objective – the distinction between strong and weak emergence is the degree of ontological distinction – and these characteristics are therefore viewed as independent of the current level of knowledge (Bedau 2002) or perspectives. Epistemological approaches which view emergence in relation to knowledge are considered in the next subsection.

2.3.2 Emergents as epistemological novelty

At the core of epistemological novelty approaches to emergence is the fact that our experiences, perceptions and explanations of emergence are dictated by our current knowledge and understanding (Christen and Franklin 2002). For example, to Silberstein and McGeever (1999, p186, quoted in Clayton 2006a) "A property of a system is epistemologically emergent if the property is reducible to or determined by the intrinsic properties of the ultimate constituents of the object or system, while at the same time it is difficult for us to explain, predict or derive the property on the basis of the ultimate constituents." Epistemological approaches may be divided into three views – phenomenological, theory or knowledge related and model change. Each of these is discussed below, highlighting the drivers for the approaches, key characteristics and potential conflicts. The subsection concludes with a brief summary of key points relating to emergence as epistemological novelty.

Phenomenological Emergence

Interest in emergence often arises from the observation of apparently novel and surprising properties or phenomena. These phenomenological qualities are often what piques interest in the concept of emergence in the first place. This has led to some approaches to emergence which concentrate on the notion of surprise or unexpected features. For example, Roland, Sipper and Capcarrerre (1999, p228) identify emergence (in artificial life systems) as behaviour or properties which is surprising in that the description of the phenomenon is "*non-obvious* to the observer – who therefore experiences surprise.". Similarly, Wolfram (2002, p288) continually refers to his 'surprise' – "But once again code 1329 has a surprise in store" – as he describes the emergence of order out of randomness or other novel patterns in simple cellular automata.

Surprise alone seems insufficient to justify labelling a phenomenon as emergent. Consider a diffraction pattern made by light through a grating. The first time a school pupil observes this, it may indeed appear surprising. However, the pattern is completely predictable and deducible from knowledge of wave interference. Further, it is hard to argue that the diffraction pattern exists at a higher level than the incoming light beam. The surprise is a result of inexperience and hence the apparent emergence is a result of our perception. Similarly, I would argue, informal definitions based on an intuitive idea of 'newness' or 'novelty' which do not specify precisely how these characteristics are defined are phenomenological in nature, being based on our particular experience of reality. As Teller (1992) observes, we need to press for more precision as to what is meant by novel if we are to make headway in understanding emergence.

Phenomenological approaches are a good starting point in the investigation of emergence, but the danger is that, over time, virtually every system that changes would be classed as emergent (Crutchfield 1994), making emergence synonymous with change. Additionally, while it is the element of surprise or perceived novelty that often alerts us to potentially emergent phenomena, a purely phenomenological definition leaves emergence as the product of human sensory perceptions (Christen and Franklin 2002); a more analytically rigorous approach is required. Epistemological approaches to emergence which aim to address theory and knowledge dependency are the subject of the next subsection.

Emergents relative to theory and knowledge

(a) Theory

Hempel and Oppenheim (1948), in their exploration of the nature of explanation, were one of the first to address theory-related issues in their definition of emergence.

"The occurrence of a characteristic *W* in an object *w* is emergent relatively to a theory *T*, a part relation *Pt*, and a class *G* of attributes if that occurrence cannot be deduced by means of *T* from a characterization of the *Pt-parts* of *w* with respect to all the attributes in *G*. [...] A characteristic *W* is emergent relatively to *T*, *Pt*, and *G* if its occurrence in *any* object is emergent in the sense just indicated." (Hempel and Oppenheim 1948, p151)

As the quotation illustrates, to Hempel and Oppenheim emergent properties (characteristics) are relative to not only a particular theory *T*, but also a particular set of micro-level entities (the *Pt-parts*) and a set of attributes. Interestingly, while Hempel and Oppenheim's emergence is not ontological, the "non-deducibility" means that it is still 'strong' with respect to the particular theory *T*.

Relational properties

Hempel and Oppenheim emphasise "the occurrence of a characteristic may be emergent with respect to one class of attributes and not with respect to another." (Hempel and Oppenheim 1948, p148) This is an attempt to counter the criticism that emergence based on the inability to infer macro-level properties from micro-level properties makes the concept vacuous. Consider the following argument which Hempel and Oppenheim trace back to Gruelling: it is a property of hydrogen and oxygen particles that when they combine, they give rise to a substance with the properties of water – therefore once this is known, the properties of water are deducible from hydrogen and oxygen. The generalisation being once a particular macro-level property has been observed to appear from micro-level entities, it can always be inferred and therefore cannot be emergent. This apparent transient status of emergents arises from the misconception that hydrogen and oxygen molecules can individually hold the property that they give rise to water. As Bar-Yam (2004) points out such properties are in fact relational properties – they only exist in relation to other micro-level components – in the relation between hydrogen and oxygen. Clarity of where claimed properties lie is important if emergence is to be demystified.

Non-deducibility and predictability

Hempel and Oppenheim define emergence in terms of non-deducibility. However, many other theory-related approaches associate emergence with unpredictability. According to Stephan (1992), Popper is the main proponent of this sub-view, although Popper also discusses emergence in terms of non-deducibility. For example, to Popper (1963, p16, quoted in Stephan 1992, p34), "[There] is the fact that in a universe in which there once existed ... no elements other than, say, hydrogen and helium, no theorist who knew the physical laws then operative ... could have predicted all the properties of the heavier elements not yet emerged, or that they would emerge."

The relationship between non-deducibility, predictability and the irreducibility which is the focus of discussion in ontological approaches will be considered in detail in subsection 2.4.3.

(b) Knowledge

Emergence is also potentially related to our level of knowledge. Subjective aspects of this were dealt with in the discussion of phenomenological emergence above. However, there is a potentially objective limitation. As Laughlin observes in his discussion of the Universe, "What we emerge from is unknowable, [...] The underlying equations of the Universe cannot be determined from what we know." (Laughlin 2005, quoted in Samuel 2002) What Laughlin is illustrating is that our inability to determine how emergents arise from micro properties is potentially a consequence of lost or hidden information. However, while an idealised all-knowing observer might be able to deduce how the macro-property arises, Goedel's theorem suggests the possibility that even an ideal observer would not be able to predict it.

The role of the observer: scale, resolution and scope

The inclusion of *Pt-parts* in Hempel and Oppenheim's definition above captures the fact that in their opinion the level of observation – the scale – is also a factor in emergence; a notion which is often forgotten (Bar-Yam 2004). Consider for example, macro-level observations of a flock of birds and micro-level observations at the level of individual atoms. Macro-level flocking patterns will appear non-deducible from the individual atoms even if bird flocking rules are known; however, when the micro-level observation is at that of the individual birds, the resultant flocking pattern is deducible from three simple rules[22].

Observation of a macro-level emergent property also depends on the observer's internal model. For example, as history shows, the visible patterns associated with the Belousov-Zhabotinsky reaction were initially dismissed by scientists as they did not fit into the theory of the time. Ryan (2006)[23] therefore distinguishes between scale and resolution. The former, he suggests, is ontological in that it is independent of how the system is represented (the model) while the latter is epistemological, dependent on the particular model or theory being used. He uses this to define a type of weak emergence:

"A property is weakly emergent iff it is present in a macrostate but it is not apparent in the microstate, and this macrostate differs from the microstate only in resolution." (Ryan 2006, p8) In this case, the 'weakness' is related to the observational model rather than degree of reducibility central to ontological approaches. Ryan claims this shows that his weak emergent property is a limitation of the observer, not a property of the system.

As Bar-Yam (2004)[24] observes, the scope of observation – the breadth of the observation of the system at both macro and micros levels – also plays a significant part in our understanding of emergence. This, he suggests, is a factor in much of the mysticism associated with strong emergence as frequently the scope of observation does not include relevant boundary conditions which affect the emergents, making them appear apparently irreducible. For example, the smell of ammonia discussed in section 2.2 appears irreducible – it cannot be explained in terms of hydrogen and nitrogen alone. However, it is perfectly explainable when the scope is extended to include the shape of their compound and nasal receptors.

While scope clearly affects our understanding and is therefore epistemological, Ryan suggests that by considering all possible scopes, we might be able to identify strong ontological emergents – "A property is a novel emergent property iff it is present in a

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[22] See the Boids model (Reynolds 1987) which shows the development of bird flocking patterns from simple initial rules.

[23] This is a preprint of Ryan (2007).

[24] Bar-Yam's (2004) approach is considered in more detail in subsection 3.2.3.

macrostate but it is not present in any microstate, where the microstates differ from the macrostate only in scope" (Ryan 2006, p10).

Model change

The preceding subsections have been concerned with the effect that theory and knowledge have on our perceptions of emergence. Interestingly, some authors adopt a more 'objective', but still epistemological approach. For these authors, emergence is related to the need to change the model – conceptual or theoretical – that is used in order to understand observed phenomena. For example, Rosen (1985, cited in Heylighen 1991) views the behaviour of a system as emergent when the existing model description can no longer be used described the behaviour. While Rosen does not himself describe his interest in emergence in either epistemological or ontological terms, I would argue that as such approaches are concerned with models of understanding, as Silberstein (2002) argues, they are epistemological approaches. Three different rationales for the change in model are considered below.

(a) Language

This need to move between conceptual or theoretical models is often associated with insufficiency in language – "Indeed, more than the fact that they 'do not exist' at the lower level, emergent properties are meaningless in the language appropriate to the lower level." (Checkland 1999) Whether this is just a human perceptual / linguistic phenomenon or a fundament issue regarding emergence is unclear. For example Epstein (1999) strongly contends that inadequacies in language should not lead us to view a phenomenon as emergent. He uses as an example the translucence of water as a macro-level property that is trivially not deducible from the micro theory of oxygen (O) and hydrogen (H) since "translucent" is not a term of the micro theory." (Epstein 1999, p34) However, as quoted in subsection 2.3.1, Ellis (2006), suggests that such language deficiencies may be a result of human perception of ontological distinctions. Thus, language inadequacy, like surprise may be a useful indicator, but not a necessary and sufficient condition for emergence.

(b) Conceptual models

Relatedly, completely different conceptual models at each level may lead us to view a phenomenon as emergent. Whether the variation in models is a fundamental one or simply a result of how we currently understand things due to current conceptual or scientific models is again the subject of dispute. The idea of 'bridge laws' are often used to attempt to clarify how the models at different levels are linked. For example, Nagel (1961) argues thermodynamics is perfectly explainable in terms of statistical mechanics, provided terms are mapped via "correspondence rules". However, according to Primas (1998, cited in Silberstein 2002), Nagel's form of theory reduction has failed in all but the most trivial cases and, as highlighted in Chapter 1, the case of thermodynamics is certainly still the subject of much dispute.

Heylighen (1991, p89) tries to objectify such approaches, stating – "Emergence is defined as a process which cannot be described by a fixed model, consisting of invariant distinctions. [...] emergence must be described by a metamodel, representing the transition of one model to another one by means of a distinction dynamics". However, again such a claim to emergence can only ever be provisional.

For Pattee, emergence of life is associated with an "epistemic cut", where it is not just that different rules exist at the biological level, they are quite different in form (Pattee 2001). So, while physical level laws are based on energy, time and rates of change, biological systems are based on measurement, memory and selection (Pattee 1997). While this at first sight appears to correspond to the ontological view of rules and hierarchy emergence discussed in subsection 2.3.1, Pattee (2001) and Rocha (2001) strongly suggest that biological systems are semiotic systems – systems where signs and symbols are used to construct meaning (Sebeok and Umiker-Sebeok 1992). For example, Pattee contends that DNA acts as a memory structure and hence a biological symbol, and with its replication rules forms a language for the biological level. So to Pattee, there are not just different languages but completely different intrinsic epistemologies and knowledge within the micro and macro levels.

What is core to the above approaches is the need to change our model of the system under investigation in order to understand the emergent phenomena. Why this occurs is not clear, although Pattee is suggesting that in the case of life at least this is a consequence of the nature of life and not just our understanding of it. The next set of approaches offers a potential reason why in at least some cases that might be.

(c) Predictability

Shalizi (2001) suggests that our move between models when describing macro-level properties is related to the effectiveness of the model in predicting behaviour – "[a] derived process is emergent if it has a greater predictive efficiency than the process it derives from" (Shalizi 2001, p115-116) – where a "derived process" captures the idea of supervenience and is the result of a mapping from a process by some sort of measurable function. Shalizi employs the concept of "predictive efficiency" to capture "the fraction of historical memory stored in the process which does "useful work in the form of telling us about the future." Therefore, in Shalizi's emergence, it is easier to predict behaviour from the macro-level model than the micro-level one.

Shalizi's approach is interesting as he manages to capture in a more scientific way some of the intuitive concepts regarding unpredictability of emergent properties and the observation that intuitively (phenomenological) emergent properties may be described more simply at the higher level scale – i.e. their complexity is reduced. In particular, he claims that the improved predictability is independent of an observer. However, the approach only applies to a very idealised world where computability is at its core. As will be discussed in subsection 2.4.1, the assumption that the world is computation-based is still the subject of debate.

Shalizi's approach to emergence is based on Crutchfield's (1994) work, which is in itself interesting in its investigation of what he terms "intrinsic emergence". Crutchfield views emergence as a "process that leads to the appearance of structure not directly described by the defining constraints and instantaneous forces that control a system. [...]. An emergent feature also cannot be explicitly represented in the initial and boundary conditions. In short, a feature emerges when the underlying system puts some effort into its creation." (Crutchfield 1994, p12) Thus, Crutchfield is interested in how the causal powers of emergents – higher level patterns – are capitalised on by a system itself.

Again, he takes a model-related approach where a subprocess within the system – an internal observer – detects new emergents by continually refining its model[25] of the system – i.e. the subprocess' environment – until it can recognise a pattern and predict its properties. This creates a causal structure which underlines the generation of the measurements (observations). Using the predictability features discussed above, the system can then capitalise on emergent patterns once they have been discovered. Thus, in this approach emergence is capitalised on through the causal structure of the system. This, Crutchfield claims, enables functionality to develop – "What is distinctive about intrinsic emergence is that the patterns formed confer additional functionality which supports global information processing, such as the setting of optimal prices [within an economy]." (Crutchfield 1994,

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[25] Crutchfield emphasises that these models are behavioural rather than cognitive.

p14) Again, like Shalizi's approach, this is highly idealised and whether the claimed added functionality is realised is questionable. It certainly has a potential function, but unless the ability to support global information processing is 'used', the potential function is not achieved.

Summary of epistemological approaches

Figure 2-5 below provides a summary of the key features of epistemological approaches to emergence that were discussed in this subsection.

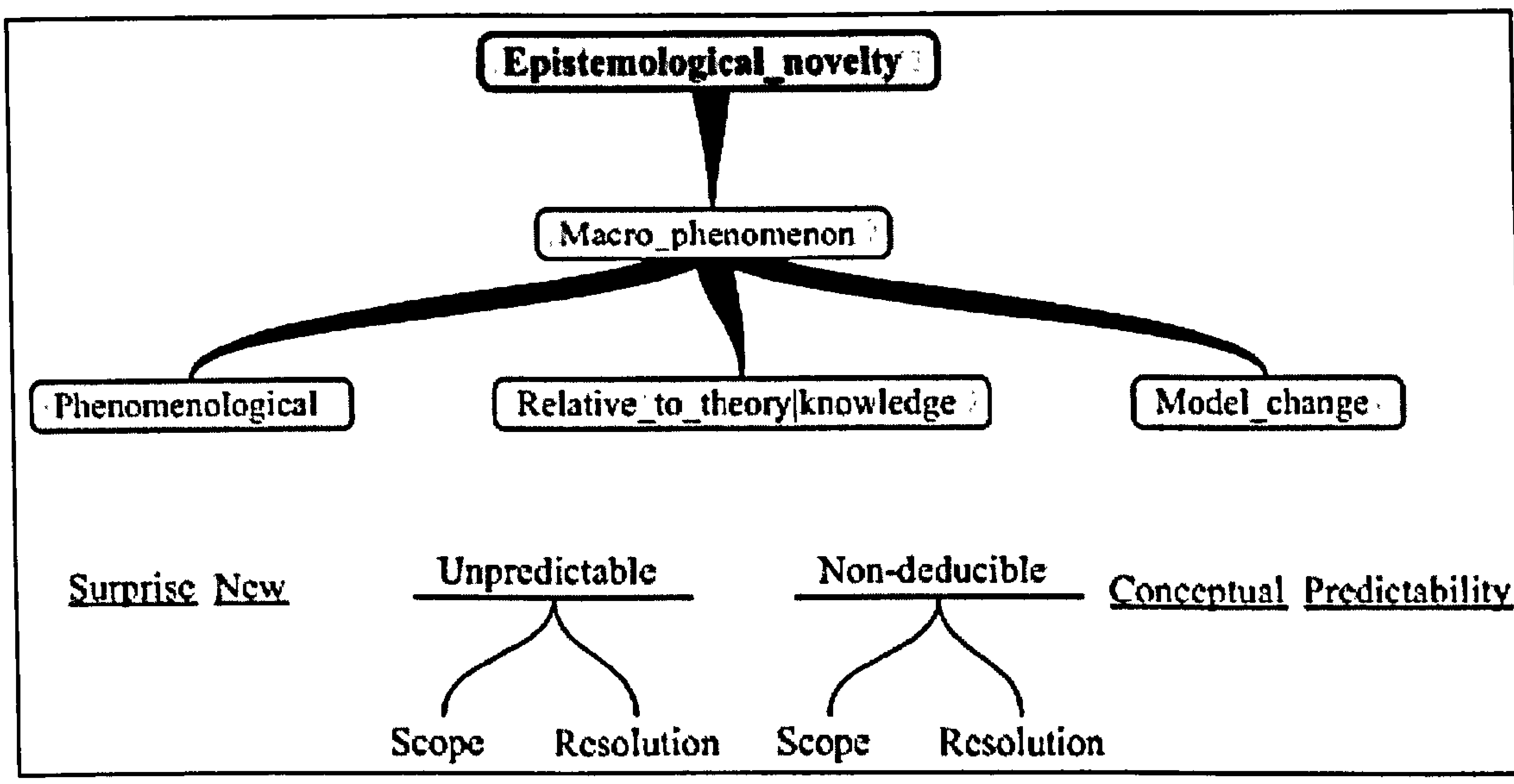

Figure 2-5: Summary of epistemological approaches to emergence

As the above discussion illustrates, epistemological approaches to emergence are concerned with how we understand macro-level phenomena rather than the fundamental nature of such phenomena. As captured in Figure 2-5 above, three types of approaches were identified. Phenomenological approaches such as surprise or new depend on the current expectations of the observer and do little to aid understanding save to hint that something might be emergent. The subview that phenomena are emergent relative to specific theories or knowledge, captured in the centre of Figure 2-5 highlights the important subjective nature of our understanding of emergence and adds rigour to discussions, aiding clarity and helping to dispel much of the mysticism associated with emergence. Emergence in this subview is generally considered either in terms of non-deducibility or non-predictability, and as Figure 2-5, right emphasises, perception of these may depend on scope and resolution. The final subset of approaches – Model_change in Figure 2-5 – considers why we have different models for macro-level phenomena and their micro-level parts. Two major differences were identified. Firstly the model changes were due to different conceptualisations - for simplicity, language is subsumed under conceptual although its effects were discussed separately. Secondly, they were a result of increased predictability. At the heart of this subview is that these new models may be a consequence of the nature of the phenomena themselves and not just our interpretations of them. To clarify the core difference between */Relative to_theory|knowledge* and */Model_change* it is useful to think of the former in terms of our choice of epistemology to use in discussing emergence and the latter in terms of the impact of the structure of epistemology or organisational structure on understanding the emergence.

2.3.3 Emergents as the product of complex systems

Product approaches to emergence have arisen in the main from the complex systems movement's attempt to understand how global system properties and behaviour – the system products – arise when multiple lower-level entities interact (Goldstein 1999, Bedau 2002). This interest has been particularly prevalent in the last 30 years, and has greatly contributed to the recent 're-emergence of emergence' as a concept of scientific interest (Corning 2002, Clayton and Davies 2006). For clarity, complex systems approaches have been split into two strands, which examine dynamics and constraints respectively. While this distinction is somewhat artificial as many approaches consider both aspects, it enables particular features to be better highlighted. For each, the rationale for consideration as emergence and potential conflicts are discussed. As these approaches tend not to be interested in the more traditional 'essence' or 'key' characteristics such as irreducibility, but rather concentrate on generation criteria, this is examined instead. The subsection ends with a brief summary of key points relating to emergence as the product of a complex system.

Emergents as the product of non-linear dynamics

The simplest 'product' approaches, view emergents as the product of self-organisation – "Emergence is what "self-organizing[26] processes produce" (Corning 2002, p19) and

[26] Self-organisation is core to complex systems thinking and is perhaps best explained by example. One of the first detailed and iconic studies of self-organisation was Gordon's (1999) investigation of ant colonies. Ant colonies appear highly organised: workers find food, soldiers defend the colony; cleaners dispose of the dead; and the queen ensures a continuous supply of workforce. The question that interested Gordon was; how does this highly organised society arise? Detailed study showed that

"[Emergence is] the arising of novel and coherent structures, patterns and properties during the process of self-organization in complex systems." (Goldstein 1999, p49) First the core properties of emergence under this sub-view is considered, followed by a more detailed look at Holland's approach to emergence which has be highly influential.

(a) Core properties: net-like structure, processes and self-organisation

Corning's definition noticeably makes no reference to higher or macro-level features which were central to ontological approaches of subsection 2.3.1. Arguably, by his definition, changes in the properties of micro-level components[27] which arise through non-linear interaction could be considered emergent. For example, individual learning through group activity which involves interaction would be an example of emergence. Goldstein's definition captures the more prevalent notion that macro-level patterns and structures that are found throughout complex systems are emergent. The 'structural' and 'patterns' emergence of social capital, economics and computational patterns would be emergent to Goldstein, while individual learning would not.

This idea of emergent structure is prevalent in complex systems based approaches. Gell-Mann, one of the founding fathers of the complex systems movement, sums this up by "apparently complex structures or behaviours emerge from systems characterized by very simple rules. These systems are said to be self-organized and their properties are said to be emergent." (Gell-Mann 1994, p99-100) Additionally, Prigogine's (Nicolis and Prigogine 1977) theory of dissipative structures addresses the formation of spontaneous macro-level patterns which develop in far from equilibrium open thermodynamic systems. Examples range from hurricanes to Bénard cells. This leads to a syntactic or organisational perspective

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it arises from a few simple rules and Gordon and her colleagues were able to develop a computer simulation, replicating the observed activity. This rise of detailed organisational structure and resultant system interactions, often from very simple rules within the system itself, can be seen throughout physical and natural systems; avalanches, hurricanes, phase changes in physical systems are all examples of self-organisation.

[27] Components are often referred to as entities within complex system approaches.

(Boschetti et al. 2004) which examines the net-like structure of the emergent macro-level features[28].

As complex systems are generally considered open, non-linear and dynamic, changing over time through self-organisation, this leads to an association of emergence with dynamical systems (Corning 2002, p24, Casti 1997)[29]. Thus, the property of being a circle is excluded from this approach, as no dynamics are involved. Similarly, the functionality of a machine is also often excluded, as it is a product of design rather than self-organisation. Approaches which view emergents as the product of non-linear dynamics, therefore, tend to concentrate on the dynamic processes which give rise to emergents rather than the supervenience types of processes typical of the ontological approaches or the perceptual or analytical processes typical of the epistemological approaches to emergence.

This dynamical perspective means that the macro-level properties – the emergents – are not just new capabilities but also recurrent patterns and processes. For example, to Funtowicz and Ravetz (1994) the oscillation of societies from supremacy to collapse and the subsequent rise of a new society is an example of emergence. Similarly, within biology, the process of cell reproduction may be viewed as emergence. Thus emergent macro-level 'properties' are structures in *space* **and** *time.* Indeed Ryan (2006, p6) argues, "emergent properties must be the result of spatially or temporally extended structures, since otherwise it would be trivial to detect their presence in the micro-state."

This has three important consequences. Firstly, the scope of observations should extend in both time and space to insure important emergent features are captured (Ryan 2006). The length of time may need to be significant in systems which display high degrees of novelty. What is critical in evolution, and other such systems, is time. For example, in evolutionary systems, while changes are introduced through variation in short timescales, the process of natural selection leads to sustainable new properties or characteristics over longer time frames. Secondly, there may be different types of emergence associated with a given

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[28] The field of Complex Networks (Barabasi and Albert 1999) investigates the net-like structures of complex systems. While not approaching the net-like structures from an emergence stance, some of the techniques are of interest.

[29] As Corning (2002, p24) notes, early British emergentists such as Lewes (1875) and Morgan (1923) acknowledged that dynamical systems give rise to emergence.

phenomenon. The emergence of consciousness may be viewed from the perspective of emerging from the physical brain at a given point in time or from simple biological cells over an evolution timescale. Thirdly, given the nature of non-linear dynamics, the system may lose historical information about its construct over time. Thus, apparent irreducibility may be due to lack of knowledge regarding how particular macro-level features arose over time.

In summary, the dynamic perspective means approaches which view emergence as the generation of a product offer the advantage that they may aid investigation of what causes emergence. However, self-organisation is itself a subject of much investigation and some debate and therefore simply equating emergence with self-organisation does little to improve understanding. Understanding the processes that occur in self-organisation and which particular types of emergence they give rise to is, I would argue, crucial to improving understanding. Holland's (1998) investigation of emergence, which is considered next, goes some way to addressing this gap.

(b) Holland's approach to emergence

To Holland (1998, p3-4), emergence arises out of complexity – "A small number of rules or laws can generate systems of surprising complexity... The rules or laws generate the complexity, and the ever-changing flux of patterns that follows leads to perpetual novelty and emergence." His investigation of emergence focuses on persistent patterns which 'emerge' from "messy" low-level interactions, examining in particular games from an agent-based model perspective. As is typical of 'product' approaches, rather than explore the definition of or types of emergence that were at the core of the majority of the approaches presented in subsections 2.3.1 and 2.3.2, Holland identifies eight concepts, listed in Table 2-1 below, upon which, in his opinion, emergence is based.

Concepts upon which Emergence is based
1. "Emergence occurs in systems that are generated."
2. "The whole is more than the sum of the parts in these generated systems"
3. "Emergent phenomena in generated systems are, typically, persistent patterns with changing components."
4. "The context in which a persistent emergent pattern is embedded determines its function."
5. "Interactions between persistent patterns add constraints and checks that provide increasing "competence" as the number of such patterns increases."

Concepts upon which Emergence is based
6. *"Persistent patterns often satisfy macrolaws."*
7. *"Differential persistence is a typical consequence of the laws that generate emergent phenomena."*
8. *"Higher-level generating procedures can result from enhanced persistence."*

Table 2-1: Holland's eight concepts upon which emergence is based

(From Holland (1998, p225-228))

Holland (1998, Chapter 7) bases his ideas around what he calls 'constrained generating processes' (cgp) – Table 2-1 above, #1; "Though constrained generating procedures supply neither necessary nor sufficient conditions for emergence, they do capture many of the important elements of emergence" (Holland 1998, p221). This captures Gell-Mann's idea of rules generating emergents but as it is less prescriptive – self-organisation is not required – it has the advantage that 'designed for' macro-level properties such as the functionality of a machine may be included as emergent.

Concept #2 in Table 2-1 captures the idea core to complex systems thinking that non-linear interactions give rise to additional properties and capabilities that could not be achieved by the system components in isolation. Thus, emergents are typically viewed as global properties which are "more than the sum of the parts" (Holland 1998, p225) or "cannot be produced by summing behaviour of individual agents in the environment" (Kubik 2003, p47). Unlike the ontological approaches described in section 2.3.1, approaches such as Holland's, which are based on the product of non-linear dynamics, do not concern themselves with the degree of irreducibility of the macro-level products. However, as highlighted in subsection 2.3.1, Bedau (2002), equates these products of complex systems to *weak* ontological emergence.

Holland highlights another important point. While macro-level emergents may appear consistent over time, the micro-level components that give rise to them may change – "[e]mergent phenomena in generated systems are, typically, persistent patterns with changing components." – concept #3, Table 2-1. For example, in the human body, organs maintain their function despite the fact that the cells from which they are composed are replaced over time. As Maturana and Varela (1980) observe in their discussion of autopoiesis[30], while the physical components of organs change, their 'organisation' is closed. This distinction of *persistent – i.e. closed – organisation* where the physical micro-level *structure* changes over time is useful.

The functionality which develops is highly dependent on the context of the emergent patterns – concept #4, Table 2-1. Thus, the system components and its environment not only influence the appearance of the macro-level emergents but also how they are then capitalised on within the system – the emergents serve a context-dependant function. This is akin to Crutchfield's (1994) intrinsic emergence discussed in subsection 2.3.2(c).

Holland notes, in his concept #5, Table 2-1, that interaction between emergents generates constraints, which further affect system behaviour. For example, high prices in the UK property market further increased the property boom. To Holland, these constraints increase the "competence" of the system, focussing the macro-level capabilities. However, given the recent down turn in the housing market, I would question the notion of 'competence' and suggest rather it focuses the system on a particular trajectory. This 'focussing' relates to attractor dynamics of non-linear systems; the system behaviour settles in a stable pattern which as Chaos Theory[31] shows is a result of non-linear interactions. This relates to weaker forms of downward causation discussed in subsection 2.3.1. The role of constraints is examined in more detail in the next subsection.

As concept #6, Table 2-1 suggests, macro-level laws or rules appear to be followed. Additionally, according to concept #8, where the persistence is enhanced these may lead to higher-level generating procedures. Thus, like Ellis (2006) and Fromm (2005), Holland recognises the layering of emergence over multiple levels (see discussion of 'Novel entities and rules' in subsection 2.3.1). Precisely what "enhanced persistence" is or how it leads to these higher-level constrained generating procedures is unclear, although Holland appears to

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[30] Maturana and Varela (1980) explore the concept of autopoiesis which seeks to capture the invariant features of living systems around which natural selection operates.. Autopoiesis is not a theory of emergence as it deals with one specific category of system – self-replicating systems. However, the identification of mutual and recursive coupling as drivers of invariant macro-level features is important, as is the notion of organisational closure.

[31] See Glick (1987) for an introduction to chaos.

be suggesting via concept #7 that differential persistence, where there are multiple generating procedures, each cycling at different timescales, may be a factor.

While Holland's (1998) book on emergence on which the above is based has been highly influential within the Complex Systems community, it is arguably about the dynamics of complex systems rather than the wider concept of emergence *per se*. That said his observations on patterns and procedures and how they lead to global properties or functionality is highly relevant to emergence.

Emergents as a product of constraints

Another prevalent 'product' view of emergence, which Holland's constrained generating procedures hint at, is that emergents are the product of constraints (Polanyi 1968, Holland 1998, Atay and Jost 2004, Bar-Yam 2004). For example, according to Atay and Jost (2004, p2-3) constraints on individual behaviour of entities that are brought about through interaction lead to "an emergent behaviour that transcends what each element is individually capable of." While constraints clearly arise within dynamical non-linear systems, the advantage of a 'constraints' approach rather than the self-organising ones of Corning (2002) and Goldstein (1999) is that manufactured and static constraints are also included. So for example, Bar-Yam (2004) includes the functionality of a machine as weakly emergent. Such approaches, like the approaches of the previous subsection, view emergents as macro-level net-like structure, processes or patterns.

Bar-Yam's (2004) approach to emergence is particularly insightful in understanding the effects of constraints. Unlike Bedau's distinction of types of emergence by the degree of reducibility of macro-level properties to their component micro-level parts (subsection 28), Bar-Yam categorises types of emergence by types of "parts-whole" relationships – that is how the micro-level parts are related to each other, the system and its environment. These constraints generate new capabilities and properties –Bar-Yam's 'emergent behaviour' – within a system. This results in the typology of emergence summarised in Table 2-2 below.

Type of emergence		**Description**	**Examples**
Type A		Emergent behaviour	
Sub-type	Type 0	Parts in isolation without positions to whole	Reductionist approach to physics
	Type 1	Parts with positions to whole (weak	Pressure, patterns on animal hides,

Type of emergence		Description	Examples
		emergence)	traffic jams
	Type 2	Ensemble with collective constraints (strong emergence)	Marriage, supply chains, Harmonic vibrations
	Type3	System to environment relational property (strong emergence)	Function of key opening a door
Type B		Dynamic emergence of new types of systems “new emergent forms”	

Table 2-2: Overview of Bar-Yam’s taxonomy of emergence

(Adapted from Bar-Yam (2004, p17))

As Table 2-2 above shows, Bar-Yam’s *Type 0* emergence corresponds to a macro-level property that is not contained in the individual micro-level entities and there is no dependency on micro-level net-like interaction which is typical in non-linear systems. This, he claims, corresponds to the extreme reductionist approach in physics which suggests that the universe may be understood through grand unified theories without recourse to structure. As there is no parts-whole – i.e. micro-macro – relation, this corresponds to the simplest form of nominal emergence.

Bar-Yam’s *Type 1* emergence arises where the position of micro-level parts and their relationship with each other lead to macro-level features. This emphasises a net-like structure of constraints – which he claims corresponds to the general concept of weak emergence – giving rise to global properties like pressure or patterns on animal hides. This interpretation of weak emergence is different from Bedau’s as pressure like other thermodynamic properties, while depending on individual micro-level properties such as position and momentum, is generally regarded as a sum of these rather than a net-like product. However, Bar-Yam argues this is an idealised case; in real-world systems impurities occur and so the relationship between particular macro-level parts does affect macro-level thermodynamic properties. This basis for classification of thermodynamic properties as weak is somewhat questionable. For example, if there were no impurities, does this mean that there would be no temperature or pressure?

Type 2 emergence, according to Bar-Yam, arises when environmental boundary conditions and global system constraints arising from the interdependencies of micro-level components combine to determine the properties of individual micro-level components – that is where the emergents display downward causation of the medium variety discussed in subsection

2.3.1(c). As an example, he suggests the self-organisation of supply chains in order to meet the individual organisation's commercial needs within a competitive market system. Bar-Yam claims "this is consistent with the notion of strong emergence as it has been discussed historically" as the resulting behaviour cannot be deduced by considering the micro-level parts and their interactions alone. There is an additional interaction with the global system constraints which means that the macro-level emergents are not reducible to the micro-level parts alone.

Bar-Yam's approach is particularly interesting as, despite the apparent irreducibility, he provides a way to capture mathematically this claimed strong emergence, using an ensemble approach[32]. To do this, he borrows from statistical physics where system ensembles – the set of possible states – are used to capture the fact that any given observation of a system is only one out of a number of possible states, and to reason formally about the system or its component parts, the full range of its phase (state) space must be considered[33]. What is particularly interesting is that it can be shown that where there are non-linear interactions between the parts, the sum of 'parts ensembles' does not equate to the system level ensemble. It is this difference which Bar-Yam suggests leads to some types of strong emergence as we can only observe specific states and not all possible states, hence the apparent irreducibility.

It must be noted that Bar-Yam's claim that his *type 2* emergence is strong is based on its claimed medium downward causation and as Bedau (2002) shows, weak emergence can exhibit downward causation. Additionally, Bar-Yam's illustrative examples are not considered, by some at least, to exhibit strong emergence. This said, Bar-Yam's *type 2* approach does highlight three interesting points. Firstly, it emphasises the role of scope in our perception of emergents – they appear irreducible because we do not observe every possible state. Secondly, as ensemble approaches may be simulated and hence are non-simply reducible, it highlights the issues with irreducibility based definitions – new techniques may change this status to reducible. Thirdly, while the technical approach is very different from Crutchfield's (1994) (subsection 2.3.2(c)) it again arrives at the idea of global processing and potential functions.

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[32] For readability, the mathematics are not described here. See Bar-Yam (2004) for details.

[33] For further explanation of statistical ensembles and phase spaces see Bar-Yam (2003, Ch1).

Bar-Yam's *Type 3* emergence – which he again claims to be a form of strong emergence – corresponds to behaviour of a system which arises out of interaction with its environment. This captures the emergent properties of functions such as a key opening a door or those of plant and animal species' roles within an ecosystem The external environment constrains the system behaviour by imposing 'boundary conditions' which limit the possible behaviour of the macro-level parts. This corresponds to Polanyi's (1968) notion of extraneous boundary conditions which he argues apply to inanimate objects and living beings, highlighting that their structure cannot be defined in terms of the laws which they harness. This type of emergence is highly context dependant – Holland's concept #4 – with different external environments giving rise to different constraints.

Finally, while Bar-Yam (2004) does not elaborate on his *type B*, dynamic emergence, it appears to be the time dependent dynamic emergence discussed in the previous subsection.

There are other approaches which examine different relationships within complex systems. For example, Jones (2002) and Fromm (2005) discuss emergence in terms of varying combinations of feedforward and feedback relations. Heylighen (1991) also examines the role of constraints in emergence by considering two billiard balls whose dynamics can be described and predicted using 6 degrees of freedom. He suggests that (i) the sticking together of the balls after a collision and (ii) the melting of one of the balls are examples of emergence, as either occurrence changes the degrees of freedom of this two bodied system – i.e. their dynamics are constrained. However, this arguably confuses change with emergence, as no new properties appear at a macro-level. It is the changed micro-level properties of the system which give rise to the new system dynamics – emergent patterns. These macro-level patterns are readily reducible to the micro-level entities' behaviour.

Bar-Yam's approach is particularly interesting for three reasons. Firstly, Bar-Yam's approach usefully highlights the role of different constraints – micro-level parts, macro-level system and relation to environmental features – which impose structure that gives rise to emergents. Secondly, it helps remove a degree of mysticism by showing formally how at least some instances of downward causation might arise – "When a system is faced with global constraints, the properties of an entire system may determine the properties of a part, without the properties of a part determining the properties of the whole system". (Bar-Yam 2004, p19) This therefore aids understanding of how a given emergence may affect the system to which it belongs – a key point in emergence at the biological and higher levels. Finally, it also illustrates how perceived irreducibility arises when we fail to take into account the relational nature of the dynamics. By failing to examine the full scope of relations that affect the dynamics, information is hidden and hence irreducibility is perceived.

By offering an explanation for strong emergence, Bar-Yam could be viewed as associating his approach with ontological emergence. However, Silberstein (2002) argues that approaches which refer to states of a dynamical system – i.e. Bar-Yam's ensemble – are epistemological approaches. Bar-Yam himself simply views it as a result of micro-macro relations and constraints. This is typical of approaches within the complex systems community and hence why such approaches have been grouped into a third category of approaches in addition to those which are examining ontological and epistemological factors. However, it should be noted that there is an element of overlap in certain case as the likes of Crutchfield (1994), Shalizi (2001) and Ryan (2007) might associate themselves with complex systems approaches to emergence. But as they are concerned with epistemological factors, they have been placed within the discussion of epistemological approaches.

Summary of product approaches to emergence

Figure 2-6 summaries approaches which view emergence as a product of complex systems.

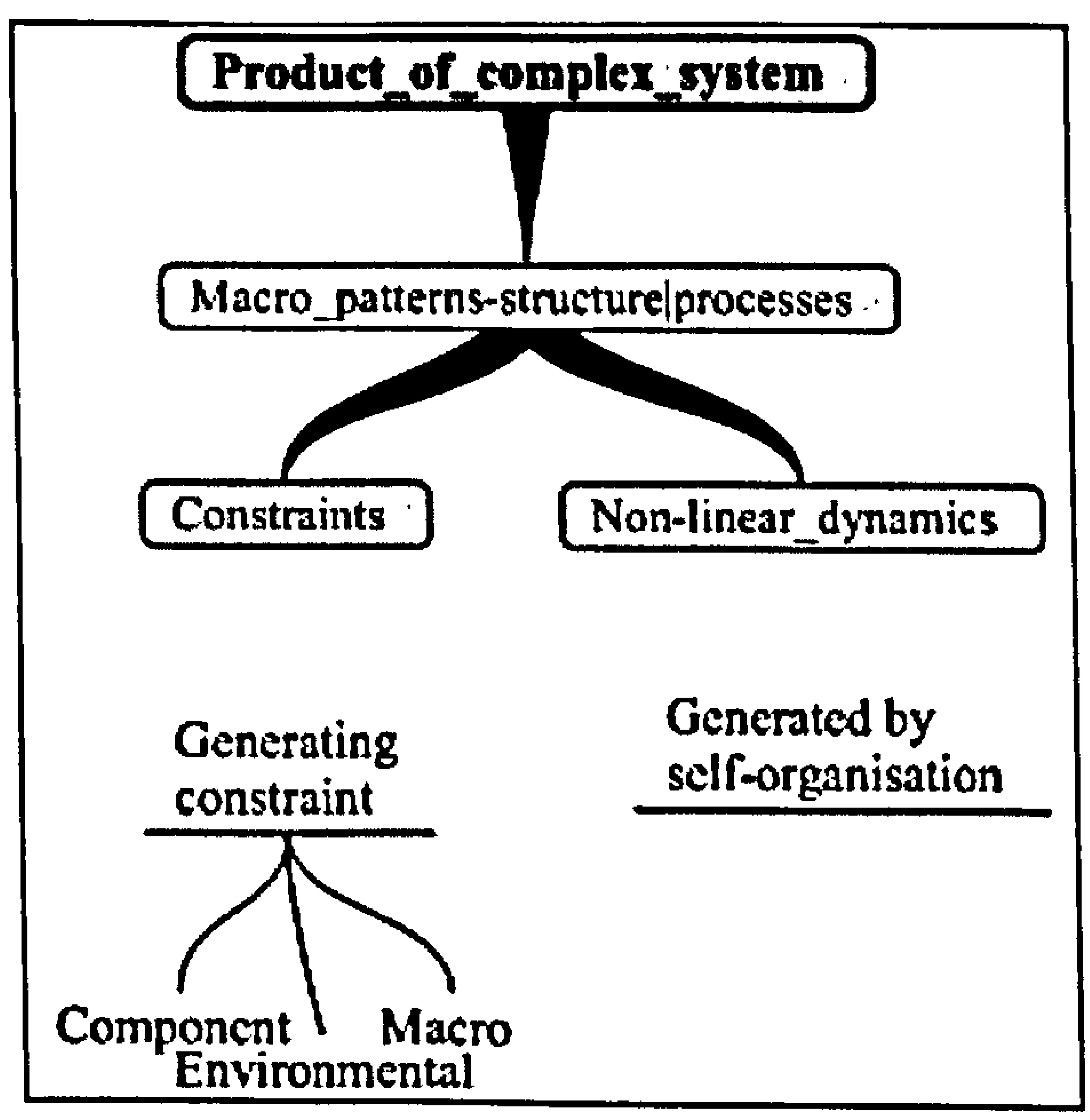

Figure 2-6: Summary of product of a complex system approaches to emergence

As Figure 2-6 above illustrates, product approaches to emergence view emergents as the product of complex systems. Emergents are typically considered as macro-level structure, patterns or processes. While inter-related, two key sub-types of approach were identified. The first – Figure 2-6, right – focuses on examination of the dynamics within the system and how it changes over time. The key to the emergence here is the non-linear relations between micro-level components. The second related approach – Figure 2-6, left – concentrates on how different types of constraints may give rise to macro-level features. As Bay-Yam observes component, macro-level system and environmental constraints all may contribute to the formation of a macro-level phenomenon. These 'product of complex system' approaches are thus concerned with the mechanics or generation of macro-level properties, which result from non-linear interactions rather than the ontological or epistemological status or these properties.

In summary, in this section three different approaches to emergence – ontological novelty, epistemological novelty and the product of complex systems – have been identified and discussed. The first set – ontological novelty related approaches – focuses on analysis of the ultimate nature of emergence and its causal powers, and have arisen from attempts to understand how apparently novel macro-level phenomena arise. Here emergence is considered in terms of the degree of irreducibility of macro-level features – properties, rules and entities – their position in a hierarchy and their causal powers. However there is considerable debate regarding what degree of irreducibility – weak, strong or nominal – is useful – i.e. not just epiphenomena – or indeed plausible. The distinction between strong and weak emergence is viewed as the degree of ontological distinction – and therefore considered as independent of the current level of knowledge or perspectives. Epistemological novelty approaches on the other hand are concerned with how we understand macro-level phenomena rather than the fundamental nature of such phenomena. Three subtypes of approaches were identified. Firstly, phenomenological views based on unclarified ideas of surprise or novelty do little to aid understanding, save to hint that something might be emergent. The second subapproach – that phenomena are emergent relative to specific theories or knowledge – is much more interesting, highlighting the subjective nature of our understanding of emergence. Emergence is considered in terms of non-deducibility or unpredictability and different scope and resolution of investigation may change our perceptions of these key characteristics. The third subapproach considers why we have different models for macro-level phenomena and their micro-level parts. The model change may relate to different conceptualisations (or language) or improved predictability. At the heart of this subapproach is that these new models may be a consequence of the nature of the phenomena themselves and not just our interpretations of them. The final set of approaches considers emergence as the product of complex systems. Here the focus is on the non-linear dynamics and the effects of constraints. Key points are that emergence extends in space and time, may be the result of self-organisation and that component macro-level system and environmental constraints affect the development of macro-level phenomena.

The review of emergence thus illustrates three very different approaches to emergence. While understanding these different aspects is clearly relevant to understanding the phenomenon itself, there is clear conflict between and sometimes within approaches. The next section considers in more detail why the variations, conflicts and confusion arise and what exactly we can conclude about emergence at this stage.

2.4 Analysis

As the preceding section illustrates, there is much confusion regarding emergence and many differing, sometimes competing and sometimes overlapping, approaches. This section examines why this has arisen, highlighting areas of conflict or issues which should be taken into account when developing a broad conceptualisation of emergence. First, in subsection 2.4.1, the reasons behind the multiple approaches to emergence are examined. Then, in subsection 2.4.2, why the confusion persists is considered. This leads to an examination of what can be concluded about the nature of emergence at this stage in subsection 2.4.3. Finally, in subsection 2.4.4, the issues that make understanding real-world emergents problematic are examined.

2.4.1 Why are there such different approaches to emergence?

In this subsection, three different reasons why such different approaches to emergence arise are considered. Firstly, the debate as to the nature of nature is considered, followed by that pertaining to the nature of our knowledge of emergence. The subsection concludes by considering how different rationales for investigating the concept of emergence affect the approach adopted.

The nature of nature – holism versus reductionism

At the crux of many of the opposing views of emergence is the split between holist or emergentist and reductionist views of nature. The actual 'nature of nature' is outwith the scope of this investigation; rather what is of interest is how these opposing stances affect views of emergence.

For strong emergentists[34] (holists), some phenomena exist which have properties that cannot be explained by the sum of their parts. Strong emergentists therefore believe strong ontological emergence exists and reject reductionism – "[strong] Ontological emergence therefore entails the failure of part-whole reductionism" (Silberstein and McGeever 1999, p182). This stance clearly has considerable implications for choice of approaches to emergence. Weak ontological emergence is viewed as merely epiphenomenalism because its 'reducibility in principle' means that the behaviour of a macro-level emergent is explainable, in principle at least, by its micro-level components. Therefore, to many strong emergentists, a weakly emergent phenomenon does not possess any independent causal powers as its actions are completely controlled by the micro-level and thus it does not have any explanatory value – "For something to be real is [...] for it to possess causal powers; mere epiphenomena have no causal work to do, and their existence makes absolutely no difference to the rest of what exists" (Kim 1992, p134). However, both Bedau (2002) and Emmeche et al (2000) argue that weak emergents do exhibit weak downward causation – see subsection 2.3.1(c). Additionally, the fact that weak emergents are reducible only in principle means that in practice macro-level properties may have to be referred to, to explain emergent behaviour. Therefore, I would argue, the concept of weak emergence is useful and is the basis for much of the exploration within the complex systems domain.

To others, strong emergentism is viewed as "uncomfortably like magic" (Bedau 1997, p3) and "antiscientific" (Epstein 2006, p38) as it appears counter to traditional (reductionist) views of scientific explanation which are based on the assumption that the world may be understood in terms of its base component parts and deducible laws. Thus, if strong emergentism is correct, it has considerable implications for scientific study. For example, phenomena like consciousness could never be explained through study of the physical brain.

Reductionists, on the other hand, believe that the nature of apparently complex objects can be explained by the sums of simpler or more fundamental objects – i.e. everything in nature can be reduced to a base form. Thus to traditional reductionists, emergence is just a lack of understanding and its only usefulness is in highlighting areas where theory is lacking. For example, chemical properties like translucence were used as examples of emergence by the

[34] Often holists are referred to simply as emergentist, however emergentists and emergentism have also been associated by some authors with weak emergence. Therefore, the term strong emergentism will be used to clarify that a holist approach is being adopted.

early British emergentists, but these properties have since been explained by the development of quantum mechanics (McLaughlin 1992).

Simple or traditional reductionism is in itself perceived as problematic as reduction to constituent parts can exclude important information. For example, the behaviour and function of biological cells cannot be explained in terms of either chemical or underlying physical properties. Increasingly there is a middle ground – non-simple reductionism or weak emergentism – "The scientific meaning of emergent, or at least the one that I use, assumes that, while the whole may not be the simple sum of its separate parts, its behaviour can, at least in principle, be *understood* from the nature and behaviour of its parts *plus* the knowledge of how all these parts interact." (Crick 1994, p11, italics in original, quoted in Corning 2002) Weak emergentism allows explanation of a biological cell in terms of its component chemicals and how they interact – i.e. the role of DNA in reproducing cells.

Strong emergentists and traditional reductionists tend to dismiss the value of the weak emergentist approach as unable to capture strong emergence in the former case and just another form of reductionism in the latter. But the weak emergentist view offers the advantage that it captures the non-linear behaviour that is found in complex systems and thus is at the heart of the 'product' approaches to emergence which are driving much of the renewed interest in the concept of emergence (Goldstein 1999, Corning 2002, Clayton 2006a). The weak emergentist approach is particularly useful as it examines how the constituent parts of emergents interact to give rise to macro-level properties. It therefore is much more suited to exploration of how emergence develops.

This adoption or appropriation of the concept of emergence by the complex systems movement, which applies it to phenomena which are not easily reducible, has reignited the holist-reductionist debate (Goldstein 1999). Of particular concern for strong emergentists (holists) is the fact that the majority of complex systems approaches assume that emergence is algorithmic – that it can be reproduced from component parts and rules which have computation at their core – e.g. Heylighen (1991), Crutchfield (1994), Holland (1998), Standish (2001), Kubik (2003), Deguet and Demazeau (2005) and Epstein (2006). Strong emergentists therefore reject the weak emergentist complex systems approaches as incapable of capturing strong – irreducible – emergence[35]. For example, Kauffman (2000), Gross and

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[35] Using Bedau's taxonomy, weak emergence is computationally hard while strong emergence is uncomputable.

Jeffries (2001) and Stadler et al (2003) question the ability of algorithmic approaches to replicate complex causal patterns and Gross and Jeffries (2001) argue that computer simulations can never display the genuine novelty which has emerged in biological evolution. However, the debate regarding simuability is still open[36] and so complex systems approaches should not be dismissed as they are useful for studying weak emergence; rather there must always be a caveat that complex systems may omit the possibility of strong ontological emergence.

The holist-reductionist distinction cannot readily be attributed to particular subject domains. For example, within philosophy of mind both approaches exist – Searle (1997) is a strong emergentist while Kim (2006b) currently favours non-simple reductionism. Further, while non-simple reductionism dominates modern complex systems approaches (Christen and Franklin 2002), people like Rosen (1985, 1991) have argued for a non-reductionist –i.e. non-mechanistic – view of nature.

In conclusion, as the name suggests, strong emergentists (holists) advocate strong ontological emergence, where as weak emergentists (non-simple reductionists) question its existence. Bedau's taxonomy of ontological emergence which distinguishes strong and weak varieties – subsection 2.3.1 – is extremely useful in surmounting this seemingly irresolvable conflict, as it allows both types of emergence to be explored within a larger framework. However, to avoid confusion and conflict, it is essential that philosophical stances are clarified when using the framework. It is only in cases such as algorithmic approaches which claim to exhibit strong emergence that significant conflict arises. In general, the conflict is a result of imprecise use of terminology or lack of clarity of underlying assumptions.

The nature of our knowledge of emergence

As Kant observes, our knowledge about the world is always relative to theory and observation and is therefore provisional in nature. Three consequences of this provisional

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[36] Gross and Jeffries (2001) perceive a non-algorithmic nature of emergence, highlighting the self-organisation of ecosystems to 'refill functional gaps' as an example of uncomputable emergence. On the other hand, as van Leeuwen and Wiedermann (2001) amongst others have shown, computation has moved beyond mechanistic Turing Equivalence and so claims of uncomputability based on non-algorithmic nature - such as "relevant effects [emergence] in nature cannot be implemented in computer models" (Gross and Jeffries 2001) - are at least open to question.

and potentially subjective nature of knowledge for our understanding of the concept of emergence are considered below.

Firstly, the fact that knowledge is continually refined through experience means that the identification of a phenomenon as emergent is always provisional. While, as discussed in subsection 2.3.2, Hempel and Oppenheim use this as an argument for epistemological approaches to emergence, ontological proponents such as (Lewes 1875) and Bedau (1997) fully acknowledge this provisional nature, but argue that our lack of knowledge does not necessarily make a phenomenon any less real. Just because further development in theory may make a particular macro-level phenomenon explainable in terms of micro-level theory, this does not preclude the existence of some phenomena for which this can never be so. Any theory of emergence must take this inherently provisional nature into account. Additionally, this provisional nature means the existence of strong emergence is subject to question. As Shalizi (2001, p115) sums up somewhat strongly, "At best we can say that we don't yet have an explanation for a particular property, so for all we know it might be emergent. To call something [strongly] emergent is therefore not to say anything about the property at all, but merely to make a confession of scientific and mathematical incompetence."

Secondly, for those advocating epistemological approaches, the consequences of the nature of knowledge on our knowledge of emergence is more restrictive. For example, to Hempel and Oppenheim (1948, p150-151) "emergence of a characteristic is not an ontological trait inherent in some phenomena; rather it is indicative of the scope of our knowledge at a given time; thus it has no absolute, but a relative character". This is saying more than emergent properties can only be provisionally identified; rather our observation of emergent properties cannot even be taken as signs of ontological levels in nature. As Silberstein and McGeever (1999, p185) observe, emergence may be a property of the epistemological nature of explanation and totally unrelated to ontological distinctions. If this were true, the concept of emergence would be of limited value, merely indicating areas where further scientific investigation is required.

While our identification of emergent properties is epistemological, this alone does not rule out the existence of absolute (objective) emergence. Contrary to Hempel and Oppenheim, if further significant scientific investigation does not resolve irreducibility then our observations of emergent properties may well be a consequence of the existence of distinct underlying ontological levels and therefore, while provisional and relative, our observation of emergents may well correspond to real and objective properties. Shalizi's approach, briefly described in subsection 2.3.2, suggests that this is at least possible. While the internal observer process assesses its world through continually refined models, Shalizi claims that in this idealised world at least, the emergence is objective (Shalizi 2001). Whether the refinement of real-world observational models will converge to a definitive picture of reality is outwith the scope of this research, but Shalizi's findings lend support to the idea that epistemological emergence may be gradually refined to indicate objective, ontological emergence.

Thirdly, as emergence is to a large extent concerned with explanation – why macro-level phenomena may not be explained in term of micro-level properties – proponents of ontological approaches frequently rejected epistemological approaches as, in their opinion, they have no explanatory value. But, explaining, as Kim (2000, p320) notes, is an epistemological activity; epistemological emergence is all we can ever actually know. Thus, epistemological and ontological approaches play two different roles within the concept of emergence. It is the epistemological version – the subjective – that we can observe and investigate, but it is the potential for objective ontological emergence linked to the epistemological that is at the core of much of the investigations of emergence. Both are valid concepts, being complementary rather than an indication of incompatibility; but if confusion is to be avoided, we must be clear regarding which version is being discussed and what abstractions may reasonably be employed.

To add to the confusion, it is often unclear whether ontological or epistemological approaches are being adopted. For example, the majority of approaches within the field of complex systems appear uninterested in the distinctions (Silberstein and McGeever 1999)[37]. The field itself has non-linear dynamics – a theory – at its core and because of its heavy use of simulation is acutely aware of what Casti (1990) terms "the modelling relation" – the relationship between models and reality. But despite the association of emergents with macro-level patterns in non-linear simulations, these patterns are viewed as reflecting the ontological reality of properties in real-world systems. Thus, many complex systems based approaches appear to assume that emergents are not epistemological phenomena.

[37] Silberstein and McGeever (1999) argue that emergence in non-linear systems may well be ontological in nature as similar macro-level patterns and dynamics are found across diverse systems. This, they suggest, is grounds for real irreducible ontological distinction in reality.

In conclusion, as the concept of emergence is intrinsically concerned with explanation of phenomena that are difficult to understand, I would argue that epistemological dimensions to emergence should not be ignored.

Rationales for exploring the concept of emergence

The emergence literature shows that, in the main, interest in the concept has arisen from attempts to address four disciplinary type 'problems'[38]:

- to explain the observed natural hierarchy – the relationship between the special sciences (e.g. Mill 1843, Lewes 1875, Alexander 1920, Morgan 1923, Broad 1925, Ellis 2006);
- to explain the relationship of the mind to the brain (e.g. Sperry 1969, Searle et al. 1997, O'Connor 2000, Chalmers 2006, Kim 2006b);
- to understand the hierarchical nature and functional persistence found within biology or other macro-level systems (e.g. Campbell 1974, Rosen 1991, Pattee 2000, Corning 2002);
- to understand and generate macro-level patterns and functionality which appear in complex (non-linear) systems throughout nature (e.g. Heylighen 1989, Crutchfield 1994, Holland 1998, Goldstein 1999, Johnson 2001).

Table 2-3 below compares the rationales for exploring emergence and the resulting consequences for the emergence approaches that were developed to address these problems.

Problem areas / Interest	**Levels of reality**	**Mind-brain relationship**	**Biological hierarchies**	**Complex systems**
Overarching questions	How are levels linked? What is the ontology of nature?	How is the mind (and its relationship to the brain) explained?	How do biological level entities and functions arise and persist?	What are the generating rules & conditions under which macro-level properties arise?

[38] Increasingly the concept is attracting wider attention. For example, Clayton (2006b) applies emergence to theological belief.

Problem areas / Interest	Levels of reality	Mind-brain relationship	Biological hierarchies	Complex systems
Discipline	Philosophy of science	Psychology, philosophy	Biology, artificial life	Physical, biological and social sciences
Causal interest	Independent causal powers	Downward causation	Power to resist perturbation	Efficient cause
Emergence approaches	Mainly ontological	Mainly ontological	Mainly & product ontological	Product
Emergence process	Instantiation	Instantiation	Dynamical	Dynamical

Table 2-3: Summary of rationales for exploring the concept of emergence

As Table 2-3 above illustrates, the underlying rationale for exploring and employing the concept of emergence has significantly influenced the approaches developed.

The interest of the early British emergentists in the relationship between the 'special' sciences and the later application of such concepts to the mind-brain problem by the likes of Sperry were focussed on '*how*' perceived irreducible relationships arise. Both 'problems' are concerned with how emergents are *instantiated* at a given instant rather than how they develop over time and gave rise to philosophical considerations which attempt to explore how ontological levels may be related without recourse to vitalism. The main difference between the two problems is that of the causal powers of the emergents: the former giving rise to the consideration of apparently independent macro-level emergents – approaches based on hierarchies and independent macro-level rules – and the latter to consideration of the effect that emergents may have on their constituent parts – the downward causation approaches. Both of these are discussed in subsection 2.3.1.

This examination of causal powers, especially downward causation, has led to some clarification in the perceived causal powers of macro-level emergents on their component parts. However, it has, to a large extent, replaced the debate about the existence of strong ontological emergence with one about the existence of strong downward causal powers. Disagreement is still significant and again it must be questioned whether we can ever really know whether strong downward causation exists or not.

While, as Table 2-3 captures, the approaches that arise from the philosophical 'how' problems are not inconsistent with those of the complex systems community, their major disadvantage as far as that community is concerned is that they do not explore how the irreducibility arises –"In proto-emergentism [British emergentism] the process of emergence remained a black box, so that one could discern both the lower-level inputs and the higher-level outputs but not how the lower was transformed to the higher during emergence." (Goldstein 1999, p54) Indeed the British emergentists believed it was unknowable – "The existence of emergent qualities . . . admits no explanation," (Alexander 1920) and "the emergence, in all its ascending grades, is loyally accepted, on the evidence with natural piety. That it cannot be mechanically interpreted in terms of resultants only, is just that for which it is our aim to contend with reiterated emphasis". (Morgan 1923, p8) So while trying to avoid vitalism, the early emergentists actually replaced it with a conceptualisation which equally does little to further understanding of how such irreducibility develops.

Interest in understanding self-organisation, where macro-level patterns and behaviour develop, and evolution of novel, persistent biological functions, led to investigations into the generating rules and conditions under which macro-level patterns and novelty develop and persist. This has resulted in approaches which view emergence as the dynamic product of non-linear interactions – subsection 2.3.3. As Table 2-3 notes, this development focus means that these approaches are interested in what Aristotle referred to as efficient cause, rather than the causal power of emergents of interest in ontological approaches. If understanding of emergence is to be improved, both the efficient cause and causal powers of emergents need to be explored. Interestingly, complex systems approaches investigating concepts such as downward causation (Bar-Yam 2004) are beginning to be developed. It is through such cross-fertilisation that inroads may be made into the difficult issue of agreement regarding the concept of emergence. But danger lies in misappropriation of terms, which may prolong the confusion.

As Table 2-3 shows, the 'product' approaches are not interested in the explanation of instantiations which are at the core of ontological and epistemological approaches. But, this is not necessarily detrimental to improved understanding of emergence as 'product' approaches are interested in the explanation of how macro-level patterns and behaviour arise over time. Indeed, if a phenomenon is to be fully understood, arguably knowledge of both how it exists at present and how it develops is required. Thus, provided it is made clear whether developments over time or instantiations are being investigated, the 'product' type approaches are complementary to other tools for investigating emergence.

The absence of purely epistemological approaches from Table 2-3 is interesting. There is little direct uptake of such approaches despite the fact that as discussed earlier in this subsection it is only epistemological emergence that we can observe. As discussed, this is mainly due to its apparent lack of explanatory power and the fact that approaches do not always acknowledge epistemological perspectives which are indeed present.

Finally as Table 2-3 illustrates, to a large extent, the approaches to emergence adopted have remained discipline specific, although as the lack of consensus and the overviews of section 2.3 illustrate, these approaches often have little in common.

In conclusion, what the above comparison of approaches illustrates is that overarching research question, discipline, causal interest, philosophical stance and nature of the emergence relation must be considered when deciding on the approach to emergence to be adopted in a particular investigation.

2.4.2 Why is confusion regarding emergence persistent?

In this subsection, three sets of issues which contribute to the ongoing confusion regarding emergence are analysed to assess how they might be minimised. Firstly, language related issues are considered, followed by conceptual confusion and finally the nature of the emergence process.

Language-related issues

The multitude of definitions of emergence and emergents arises to a large extent because of different rationales for employing the concept and from differing philosophical stances. For example, complexity scientists are interested in the product of complex systems; hence the 'product' type definitions of subsection 2.3.3 and philosophers, interested in the nature of nature or the nature of explanation, have concentrated on relationships between levels (subsection 2.3.1) and theory of knowing (subsection 2.3.2). However, these different purposes do not fully account for the degree of confusion and disagreement. Three other language-related causes can be identified.

Firstly, there is inconsistent use of such key terms as emergence itself. Further, the use of imprecise phenomenological terms like surprise or predict – see subsection 2.3.2 – leads to ambiguity and confusion and should be avoided. Additionally, seemingly disjoint terms may in fact overlap, adding to the confusion. Consider the difference between Silberstein and McGeever (1999) and Bedau (2002). To Silberstein and McGeever (1999, p186) "A property of a system is epistemologically emergent if the property is reducible to or determined by the intrinsic properties of the ultimate constituents of the object or system, while at the same time it is difficult for us to explain, predict or derive the property on the basis of the ultimate constituents." This clearly includes macro-level properties arising out of nonlinear dynamical systems. Thus, Silberstein and McGeever's epistemologically emergence includes Bedau's weak emergence despite Bedau's very firm claims that his is ontological in nature as it is a result of real ontological properties and not just a limitation of our knowledge.

Secondly, confusion may also arise from insufficiencies in language itself – we may not have developed language or tools which can adequately capture the concept of emergence (Rosen 1991, Kauffman 2000, Strogatz 2003). This suggests that we might not yet have achieved a state of understanding that allows formal definitions which encompass the full range of what is understood by emergence; rather broader definitions which enable more detailed investigation in specific contexts may be more useful given the current state of knowledge and lack of consensus.

Finally, these insufficiencies in language may actually be a result of the nature of the concept itself. Like many concepts in philosophy – ethics being a prime example – emergence might be intrinsically fuzzy. It might be that trying to use ever restrictive language to capture the concept may lead to a vacuous concept.

Conceptual confusion

The definitional difficulty appears to be more than a simple lack of clarity or misunderstanding of discipline specific or ambiguous terminology. As Wittgenstein (1954) observes, confusion may also arise because problems or concepts are described in vocabulary designed for other purposes resulting in "category error". This is certainly the view of strong ontological emergentists, who criticise the use of the concept by complexity scientists. The claimed category error arises from the fact that complexity scientists tend to explore the product of non-linear interaction and are not interested in downward causation and so, to strong emergentists, are not exploring emergence, as property irreducibility and downward causation are missing. While adopting a more discerning approach – excluding everything but strong ontological emergence in the concept – may reduce conceptual confusion, this would have the disadvantage that cross-fertilisation of ideas from both communities would be lost and, as the existence of strong emergence is questioned, the whole concept may then turn out to be vacuous. As long as care is taken to make explicit which features or types of emergence are being discussed in a particular context then a broad spectrum approach such as suggested by Bedau offers considerable advantages over a narrower one. Two areas of potential conceptual confusion, which will need to be addressed if a broad conceptualisation is to be successful, are clarified below.

Firstly, perpetual novelty or creativity is a recurrent theme in biological evolution and hence some approaches to emergence. For example, Holland (1998, p224) talks of the "perpetual novelty that attends systems exhibiting emergence". According to Collier and Muller (1998), this novelty is founded in the acquisition [creation] of new capabilities. Corning (2002), however, makes an important point when he warns, "the term [emergence] is frequently used as a synonym for "appearance", or "growth", as distinct from a parts-whole relationship". This, he suggests, significantly contributes to the confusion surrounding emergence. For example, Moran (2002) argues that creativity is emergent. But, while creativity may lie in the individual, and while influenced by other members of the group, it is unclear exactly what the micro-level components of creativity might be. Emergence and creativity/novelty are not synonymous and care must be taken to distinguish between creativity and emergence. It should be emphasised that even within the complex systems movement, emergence is generally considered different from evolution; micro-level change, unless it is a result of downward causation, is outwith the concept of emergence and so evolutionary changes which arise from copying errors are not examples of emergence. That said, creative systems such as the biosphere do produce emergence and, therefore, insight into novelty and creativity, may aid understanding of emergence.

Secondly, the tendency of complexity scientists to equate emergence with the product of complex systems is also misleading. As discussed in subsection 2.3.3 while individual learning, which results from interaction with others, might be considered the 'product' of a complex system, the lack of macro-level features makes it inconsistent with the majority of approaches to emergence. Similarly, the micro-level changes in Heylighen's billiard balls discussed in the same subsection appear to confuse change with emergence. Care must be taken to distinguish change from emergence as they are two different concepts.

In conclusion, to avoid conceptual confusion within a broad approach to emergence, care must be taken to exclude features which do not relate directly to a broad but normative approach to emergence.

The nature of the emergence process

The philosophical and complex systems based approaches also display two fundamentally different interpretations of the process of emergence. In general, philosophical emergentists investigate the synchronic structure of the world (Kim 2000); that is, they are interested in how various levels are linked, ultimately to the lowest level known at a given instant. On the other hand, within the complex systems movement, emergence is the process that gives rise to new macro-level features from micro-level rules (Gell-Mann 1994). There is a subtle, but important difference in these two perspectives – unlike the philosophical view, the complex systems community takes a dynamic view and is interested in the diachronic structure of systems and their global properties[39]. Thus, as Figure 2-7 below illustrates, what each discipline refers to as emergence is actually different processes – synchronic emergence in the case of philosophers and diachronic emergence in the case of complexity scientists.

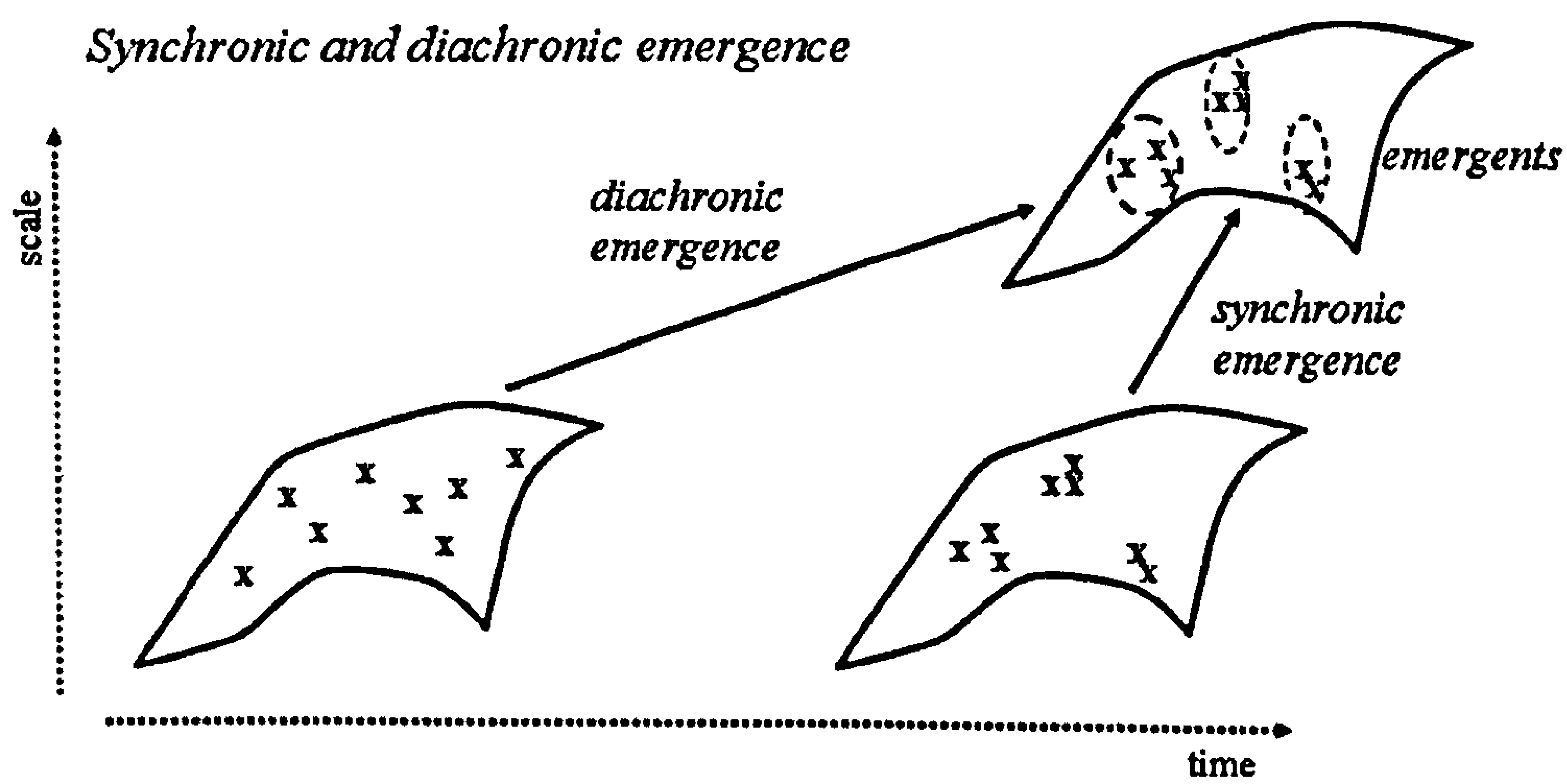

Figure 2-7: The relationship between synchronic and diachronic emergence

This difference has four implications. Firstly, as Figure 2-7 above illustrates, as each discipline is referring to different processes when it uses the term emergence, it adds to the general terminology and conceptual confusion – synchronic emergence refers to a logical property whereas diachronic emergence refers to a dynamical property. Secondly, synchronic investigations are concerned with how we interpret the world in which we live and diachronic with the development of emergents and levels. As Beckermann (1992b, p110) observes, the former is concerned with instantiation and the latter with transition. This gives rise to very different investigatory questions and emphasises different emergent properties between the two disciplines, which in turn gives rise to interest in causal powers and novelty respectively. Thirdly, as the emergence process, and therefore the 'emergence relation' which links micro and macro-level properties, is different in both cases, this may

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[39] Note, recently there have been some moves within philosophy to consider emergence as a dynamic process. See Emmeche et al (1997), Collier and Muller (1998) and Ellis (2006).

give rise to very different views on the perceived irreducibility of the emergent. For example, if the emergent is a product of non-linear but deterministic dynamics then examination of synchronic emergence alone may lead to the emergent being perceived as irreducible as it depends on specific initial conditions which are unknown; perceived irreducibility may be the result of lost information in deterministic non-linear systems. Fourthly, this synchronic – diachronic confusion is further compounded by the fact that stable macro-level properties cannot be adequately captured through single instantiations in time. For example, consider Bénard cells where the emergent pattern has already been established – i.e. synchronic emergence. The convection pattern may only be seen if we observe the system over time. Thus, 'logical' emergents may extend in both space and time – that is 'instantiations' of emergence can be dynamic. So even if the logical synchronic form of emergence is being investigated, change over time should be taken into account.

In conclusion, the different perspectives on the nature of the emergence process have implications for investigations of emergence: it is necessary to be explicit regarding the nature of the emergence relation – logical or dynamic - that is being discussed; and the dynamics of the system in which the emergence occurs should be considered in all cases.

2.4.3 What may be concluded about emergence?

As the preceding review and discussions illustrate, there is still considerable disagreement and confusion as to what exactly constitutes emergence. It is therefore impossible at this stage to extract definitive conclusions as to the essence of emergence. However, it is useful to review the different claimed key characteristics to examine which are worthy of further consideration. The subsection begins by considering two claimed characteristics which appear to be core to most approaches to emergence – *micro-macro relation* which gives rise to *novel* properties. The usefulness of the other claimed key characteristics which were identified in the review are then analysed. As noted in Chapter 1, section 1.3 and further discussed in Chapter 3, subsection 3.1.3(a), this research is interested in explanation – description of the instantiation of emergence, its causes and behaviour. Therefore, the other claimed key characteristics identified from the preceding review are grouped and discussed within these three themes. The subsection ends by considering whether different types of emergence can be indentified and whether this is a useful way of considering emergence.

(a) Core characteristics: Micro-macro relation and novelty

The diversity of approaches, lack of agreed definition and unresolved philosophical debates mean that there is little consensus on core or key characteristics associated with emergence. However, as the examples of section 2.2 and the review of section 2.3 show, the majority of approaches consider emergence as the process whereby micro-level components give rise to novel macro-level properties or phenomena which are not held by the micro-level components. An element of novelty is essential, as without this, the macro-level properties are simply reducible to, and explainable in terms of, the properties of their micro-level components. However, novelty itself is insufficient. Indeed, if emergence is not to become synonymous with change, then this appearance of macro-level (higher-level) features is essential. Assuming non-vitalism, these macro-level properties are at a minimum 'physically determined' on micro-level components, and hence, the property of 'being emergent' may be considered a relational property, lying in the relation between the macro-level property and its micro-level constituent components. This relation between micro and macro components will be referred to as the *emergence relation* throughout the thesis.

'Physically determined' is used here to capture Beckermann's (1992b) notion that it is the micro-structures of the lower-level components which give rise to the macro features. This notion will be used in preference to that of supervenience to avoid the ongoing debate as to the relationship of supervenience to emergence (Beckermann 1992b, Collier and Muller 1998, O'Connor and Wong 2005). 'Physically determined' in the sense used here avoids the notion of dependency which according to Beckermann is inherent in supervenience, focussing rather on (ir)reducibility which is at the crux of more recent emergence debates.

Having established these two core characteristics, the characteristics associated with the instantiation of emergence are considered next.

(b) Instantiation of emergence

Three key questions are of relevance to discussion of the instantiation of emergence. Firstly what are the explanatory-related characteristics of the micro-macro relation – i.e. the meta-relational characteristics of emergence? Secondly, is emergence logical or dynamic? And thirdly what counts as a macro-level emergent phenomena? Each of these is discussed in turn.

(i) Meta-relational characteristics of emergence

While the more recent ontological approaches tend to examine the degree of irreducibility of the macro-level properties to those of the micro-level components, non-deducibility and unpredictability have also been suggested as key characteristics of emergence. For example, Hempel and Oppenheim (1948) define emergents as "cannot be deduced" (see subsection 2.3.2) and to Emmeche et al (1997, p84), emergence is "formulated as the idea that there are properties at a certain level of organisation that cannot be predicted from the properties found at lower levels." In this subsection, why these variations have arisen is first examined, followed by consideration of the relevance of unpredictability, non-deducibility and irreducibility in turn.

Much of this variation has arisen from imprecise use of terminology and preliminary, incomplete considerations by the early British emergentists (Stephan 1992). A common misunderstanding is the lack of distinction between predictability and determinism. For example, consider a simple physical system which consists of a double (hinged) pendulum – one pendulum attached to another moving in anti-phase. The motion of the pendulums follows a non-simple path, appearing unpredictable, with potentially differing paths of motions each time the pendulum is restarted. This apparent unpredictability is actually a result of chaotic dynamics, determined by non-linear ordinary differential equations which are completely deterministic. The apparent unpredictability arises from sensitivity to initial conditions as opposed to an inherent randomness. The discovery of the mathematical basis for these chaotic properties in the latter part of the last century makes the unpredictable patterns of such systems completely explainable – determinable – and deducible in principle at least in terms of the equations of motion and initial conditions. Despite this determinism and deducibility in principle, the motion is still unpredictable because of inaccuracies in observation of the initial conditions. So unpredictability in this sense is a result of non-linear dynamics and therefore relevant to emergents which are the product of complex (non-linear) systems and hence Bedau's view of weak emergence. Clearly, it would not be relevant to thermodynamic properties or that of being a circle.

Unpredictability may be a useful guide to the existence of emergence, if emergence is to be associated with the product of complex systems. However, two potential issues must be addressed. Firstly, care must be taken as unpredictability may also be associated with indeterminism. Consider a random process which does not follow a deterministic formula. In any given instance, it is unpredictable; but when considered over a large enough number of instances, its outcome will follow a probability distribution and therefore is statistically predictable. As O'Connor and Wong note, "While seeing how an emergent property would be unpredictable from a certain, limited empirical standpoint is a useful way of getting a fix on the concept, this is but a consequence of its core metaphysical features." (O'Connor and Wong 2005, p8) Secondly, unpredictability, in some senses at least, is not necessarily the property of the emergent relation; rather it is a property of an individual's level of knowledge and point of view, and it is therefore phenomenological. For example, we may not be able to explain how the mind arises from the physical brain nor determine the exact process through which this occurs, but we can predict through experience (i.e. statistics) that it will emerge. This, according to Lewes (1875), is part of the core nature of emergents – "[emergents] can only be learnt by experience of their occurrence; hence they are unpredictable before the event." (Morgan 1923, p5) The preceding discussions illustrate that failure to clarify exactly what is meant by predictability has greatly contributed to the mysticism surrounding emergence (Hempel and Oppenheim 1948). The 'relative predictability' approach that was core to Shalizi's approach discussed in subsection 2.3.2, potentially offers a much more scientific assessment. However, as discussed in subsection 2.4.1, its reliance on computability means that it too can only be a guide. In conclusion, while the above issues make unpredictability unsuitable as a defining characteristic of emergence, examination of unpredictability will provide useful insight into the different underlying conceptualisations of emergence. Unpredictability is therefore a useful 'essence' or key characteristic provided how it is being interpreted is clearly specified.

The association of emergence with non-deducibility dates back to the early British emergentists. For example, Broad (1925) argues that emergent properties "cannot even in theory, be deduced from the most complete knowledge of the properties [of micro-level components]". However, in more recent times non-deducibility is more readily associated with an epistemological view. For example, as discussed in subsection 2.3.2, Hempel and Oppenheim express emergence in terms of deducibility, when arguing for an epistemological approach to emergence. Likewise, Epstein (2006, p34) is of the view that "emergence, as nondeducibility, is always *relative* to some theory (some set of well-formed formulae and inference rules)." So according to Stephan (1992) in his historical discussion of conceptualisations of emergence, 'deduce' like 'predict' is epistemological rather than ontological. However, I would argue that this distinction is just a question of semantics as Broad clearly held an ontological view.

Examining the emergent relation in terms of irreducibility appears to be the preferred form in more recent discussions. The irreducibility refers to the degree to which the emergent may or may not be explained or deduced by consideration of its component parts. At the crux of irreducibility views is that the irreducibility is not an epistemological function, rather it is absolute – i.e. ontological in nature. This approach is not without its problems, mainly due to lack of clarity of epistemological status as discussed in subsection 2.4.1 – i.e. perceived irreducibility may lie either in the state of current theoretical knowledge or in the algorithmic complexity of the interactions which gives rise to the emergent. Whether irreducibility relative to resolution (theory and scale) or scope, or absolute irreducibility is being discussed must be clarified. Further, even where absolute, ontological irreducibility is being claimed, it must be remembered that it can only ever be provisional as improved theoretical understanding or novel mathematics may in future change how the reducibility of emergents is viewed.

The distinction of the degree of irreducibility – strong versus weak – is a recurring theme and, as discussed in subsection 2.4.1, is useful as it enables both strong and weak emergentist views to be accommodated. But as the definitions of what exactly is meant by strong or weak vary, clarity is essential. Additionally, as the terms strong and weak are equally applied to downward causation, it is important to distinguish what is being referred to.

The term weak, while usefully capturing the middle ground between simple reducibility and irreducibility, is still problematic. Bedau and others use it to describe macro-level phenomena or behaviour that is reducible in principle only, but not in practice. Bedau's requirement that the macro-level phenomenon is determinable through 'simulation only' suggests he is trying to capture the idea that there is no short cut to express the macro-level property or behaviour. While it is reasonable to assume that this difficulty arises from non-linear interactions, this does not mean that all macro-level properties which arise through non-linear interactions are weakly irreducible in this sense. Some might still be simply reducible.

In conclusion, consideration of the above meta-relational properties shows that while the emergence relation is a relation between a macro property and its constituent micro-level component parts, the nature of this relationship is still very much debated, arising in the main from different approaches to emergence. Two important points are worthy of note. First, we need to take cognisance of potentially different meanings of non-deducibility, irreducibility and their degree – i.e. strong or weak – or indeed any emergence related terminology and make explicit what we mean by them where possible. Secondly, whether we can ever know whether a phenomenon is ontologically irreducible or non-deducible is unclear, given that our knowledge of it will always be epistemological.

(ii) Logical and dynamical

As discussed in subsection 2.4.2, opinion is divided as to which processes, synchronic or diachronic, is the 'real' process of emergence. As Collier and Muller (1998) quite rightly argue, emergence cannot be fully understood or explained if we cannot explain why it occurs or persists. This strongly suggests that the emergence process must be considered from a dynamic perspective. However, I would argue that this does not prevent us examining what the logical emergence relation might be within an overarching dynamical perspective. Indeed, to fully understand emergence both are arguably required.

(iii) Emergents may be entities as well as properties

Much of the philosophical literature discusses emergence in terms of emergent properties. However, when discussing novel phenomena such as the Web or the structure of the universe it is common to conceptualise these as an emergent entity as opposed to an emergent property. For example, it is the Web which we conceptualise as emergent and discuss as an entity rather than its property of providing instant global access to information. Similarly, we conceptualise atoms rather than particular properties these macro-level entities hold. Discussing the Web or atoms as emergent may be considered a shorthand for saying their particular properties are emergent. Given these entities are radically novel and that the properties they possess appear unique to the entities, I contend, this is a useful shorthand.

In some of the examples of section 2.2, the properties alone do not, currently at least, seem to explain the entity. For example, while a number of metacognitive properties such as reasoning and self-awareness can be identified, even in combination they do not appear to satisfactorily capture what is meant by mind. What such macro-level entities have in common is coherence, stability, a high degree of complexity, apparent causal powers and radical novelty not found in their micro-level components and it, therefore, seems reasonable to consider the entity itself as being emergent.

In conclusion, whether the entity is epistemological or ontological depends, of course, on philosophical perspectives. As the existence of properties is also the subject of philosophical debate (Swoyer 2000), lack of metaphysical clarity provides no justification for rejection of entities as emergent.

(c) Generators of emergents

Generators of emergence are only really considered by the 'product' approaches and, as the review of subsection 2.3.3 highlighted, these, by and large, assume non-linear dynamics are at the core of emergence. This view may be too restrictive if all of the putative examples of section 2.2 are to be included as emergent. For example, if being a circle is to be considered emergent, then the product of non-linear dynamics is too restrictive as it does not allow for such static examples of emergence.

Viewing emergence as the product of non-linear constraints, as suggested by Atay and Jost (2004) appears more useful as it is compatible with static emergence and is supported by the likes of Ellis (2006) and Ryan (2006, p6), who shows that "non-linearity is a necessary condition for [his definition of] emergent properties". While compatible with the majority of examples of section 2.2, the exception, as alluded to in subsection 2.3.3, is that of thermodynamic properties. In this case, there is no non-linear constraint leading to macro-level properties such as temperature or pressure.

The emergence associated with thermodynamics appears much more epistemological in nature and is perhaps more a result of a reduction in information; these thermodynamic properties are based on statistical averages of micro-level properties and so when viewed at the macro-level there is a reduction in information[40], which is very similar to the reduced macro-level information which arises from micro-level constraints. So in this instance the examination at a particular resolution appears to be a potential generator of emergence[41]. This should not be dismissed lightly as mere epiphenomena as it is at this thermodynamic level that both we and simple organisms measure and react to temperature. It is this relation between reduction in information required to understand a phenomenon and emergence that Shalizi is trying to capture in his approach discussed in subsection 2.3.2. Thermodynamic level theory is a better predictor of behaviour than micro-level theories as we cannot know all the micro-level variables.

The causes of the constraints or reduction in information may be varied. While typically the constraints arise from micro-level interaction, as discussed in subsection 2.3.3, Bar-Yam has

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[40] Reduction in information is an over simplification. Intuitively what occurs in the thermodynamic and related examples is that much of the information can be thrown away at the macro-level and the macro-level behaviour can still accurately be predicted. This is often viewed as a reduction in complexity, but what exactly is meant by complexity is, like emergence, a topic of much debate.

[41] While, to some authors such subjectivity cannot be a generator of emergence, this possibility is important as shall be seen in Part II.

illustrated that macro-level or environmental constraints may also have causal powers in that they help generate additional macro-level properties. These constraints may of course arise from self-organisation, but equally if we are to consider the likes of a function of a machine as emergent, manufactured constraints should be allowed.

In conclusion, the review illustrates that generators of emergence may lie in: (i) self-organised or manufactured constraints found at the micro-level, macro-level, or the environment or (ii) in epistemological related conditions. As there is still debate regarding whether emergence can only arise in a complex system or the ontological status of emergents, these potential generators, while key characteristics, cannot be considered defining characteristics.

(d) Behaviour of emergents: Causal powers

As subsection 2.3.1 illustrates, the ability of a macro-level phenomenon to play a causal role in its surroundings, be it at the macro or micro-level, is often viewed as a necessary condition for emergence. The degree of the powers required – strong, medium or weak – is debateable. For example, while to many philosophers the possession of strong downward causal powers is what distinguishes emergents from epiphenomena, its existence is one of the main controversies surrounding emergence (Bedau 2002, Chalmers 2006), with claims and counter claims often arising out of inconsistent logic (Kim 2000).

It is not just the degree of reducibility that is debateable, whether causal powers are merely phenomenological – a result of our individual perceptions – or ontological features is open to debate. For example, whether strong macro-level rules exist or are a product of our interpretation of the behaviour of macro-level phenomena must be questioned. This potentially epistemological nature means that the role of scope and resolution in perceived causal powers should be considered.

Whether perceived causal effectiveness is an ontological property or whether it is epistemological, resulting from our state of understanding or observational resolution, is to a certain extent moot; if we gain fuller understanding of the system and its behaviour by considering emergents to have causal powers then 'causal power' properties of emergents are, I would argue, a useful concept. For example, while the mind may or may not be reducible in principle to the brain, when discussing the power of leadership say, it is much more effective to discuss this in terms of psychology rather than physical brain activity. Thus, in conclusion, properties which describe the causal powers of emergents in terms of macro-level or downward causation are important. However, the issues surrounding causal power mean that it would be unwise to consider the existence of causal powers alone as a defining property of emergence.

(e) Types of emergence

As the literature review of section 2.3 illustrates, there have been a number of attempts to identify typologies of emergence. The rationale behind typologies is that each identified type has specific characteristics – be it generators in the case of Jones (2002) or meta-relational properties in the case of Bedau (1997) – which permit extrapolations and generalisations regarding such characteristics and their consequences to be extended across the specific type. However, these typologies, like definitions and general approaches to emergence, are subject to dispute. For example, Bedau's typology insists that emergence is ontological in nature, therefore excluding epistemological aspects. The characteristics of the typologies of emergence, referenced in the review of section 2.3, are summarised in Table 2-4 below. The typologies are classified to a particular approach depending on type classification. For example, while the likes of Bedau (1997) does mention complex systems in his typology, it is match to an ontological novelty approach only as the type classification is based on ontological properties only.

Characteristic / Typology	Concepts vs. emergence	Type rationale	Type classification	Approach
Bedau (1997)	Emergence	Ontological status	Degree of irreducibility	Ontological
Jones (2002)	Emergence	Generators	Organising relations	Complexity
Bar-Yam (2004)	Emergence	Generators	Relation of part to system/environment	Ontological/ Complexity
Fromm (2005)	Emergence	Generators	Feedback/forward relations	Complexity
Ellis (2006)	Emergence	Generators	Action and feedback	Complexity
Stephan (1992)	Concept	Approaches to emergence	Key characteristic	Ontological/ Epistemological

Character-istic / Typology	Concepts vs. emergence	Type rationale	Type classification	Approach
Silberstein (2002)	Concept	Approaches to emergence	Ontological/ epistemological + key characteristics	Ontological/ Epistemological

Table 2-4: Summary of characteristics of existing typologies of emergence

As Table 2-4 above, column 2 illustrates, the typologies can themselves be classified into two types. The simplest are typologies such as Bedau (1997), Jones (2002), Bar-Yam (2004), Fromm (2005) and arguably Ellis (2006) who consider types or classifications of the phenomenon of emergence. As columns 3 & 4 capture, in these typologies the classification is, in general, based on the type of generator of the macro-level phenomena or on specific characteristics of emergence. This means that the classes within the typology tend to be either distinct or inclusive. As the final column illustrates, these phenomenon-based typologies are applicable in ontological novelty or product of complex systems approaches to emergence only. They therefore do not capture key characteristics or even putative emergents which different approaches might deem core.

The other set of typologies such as Stephan (1992) and Silberstein (2002), consists of typologies of approaches to, or conceptualisations of, emergence – Table 2-4, column 2. These are classified according to perceptions of emergence and do not offer a unified or systematic picture of the concept of emergence as, not unexpectedly, like the concept of emergence itself, the types may overlap without a clear common thread. These are interesting, I argue, as they aid communication of at least some of the differing conceptualisations that exist, although neither includes complex systems perspectives directly. Whether they could be used or further developed to aid extrapolation and generalisation regarding properties or behaviour across all the different approaches to emergence is worth further consideration.

2.4.4 Why is understanding real-world emergents difficult?

This subsection draws on the preceding literature review and identified conflicts to consider what it is about emergents and how we observe and analyse them that makes understanding difficult.

(a) Ontology of emergents

A core reason why it has proven so difficult to understand emergents in full is the ontology of phenomena which fall into the category of emergence. As discussed in subsection 2.4.3, emergents are generally considered as macro-level phenomena which arise out of micro-level parts. Explanation of an emergent in terms of its micro-level constituent parts alone has, in general, proven extremely difficult which is of course what led to the concept of emergence itself. Additionally, as discussed in subsections 2.3.3 and 2.4.3, many, if not most, emergents arise within open complex systems. These two features make the explanation of emergents difficult for three key reasons.

Firstly, it may be difficult, if not impossible, to identify the causal influences which give rise to an emergent. This arises for four reasons.

(i) Frequently, the micro-macro relation is not a simple one; rather multiple heterogeneous layers of emergence may be built on top of one another, obscuring the contributing causes to the micro-macro relationship as information is lost over time due to the non-linear, evolving nature of the relations. Biological evolution is a prime example of this as there is no longer sufficient information within the biosphere to definitively tell us how, for example, cell reproduction or specific species such as the dinosaurs or man arose. Of course we can, and do, try to reason scientifically about how they might have arisen, but that is different from being able to directly identify causal influences from the system itself.

(ii) The heterogeneity is particularly obscuring as the multiple layers of emergence do not necessarily correspond to complete levels. This means that it is not simply a matter of replacing micro-level explanation with macro-level explanation; multiple interconnected levels of explanation may be required. Consider the role of DNA in biological systems. While DNA serves a function at the biological level, the DNA itself is a chemical, which obeys chemical laws – i.e. micro-level rules. As Silberstein (2002, p100) observes, this gives rise to "multilevel descriptions of causal mechanisms that mix different levels of aggregation from cell to organ back to molecule". Thus, multiple 'levels' of causation must be examined if emergents are to be fully understood.

(iii) Apparent internal system 'subjectivity' may arise due to the ontology of the system. By this, I am trying to capture two related ideas: Pattee's (2001) idea that at least biological emergence, if not other more 'complex' forms of emergence, arise due to what he terms an internal "epistemic cut", and Crutchfield's (1994) idea, which is further developed by Shalizi (2001), that intrinsic information processing within a system enables the system to 'capitalise' on parts of itself, leading to emergence. Whether this subjectivity is a separate reason, distinct from the multiple heterogeneous layers of emergence discussed above, is I argue moot. I emphasise it separately because I contend it will aid clarity. In particular, it emphasises that the emergence system – the complex causal system which gives rise to the phenomenon under consideration– is not only heterogeneous but that its internal organisation and information processing structure is important to explanation of its generation and behaviour. This is the subject of related work (McDonald 2005, McDonald and Weir 2005, 2006) which is not included within this thesis due to volume considerations. Thus, internal subjectivity will not be developed further here, save for its general consideration within understanding of emergents.

(iv) The radical openness of many complex systems (Chu et al. 2003) means that it may be impossible to identify all causal factors, as it is impossible to close the system. As Chu et al argue, no matter how wide the boundary of the system under investigation is set, we cannot guarantee that an external factor will not influence the development of the emergent. For example the development of the higher-level cognitive features of the human brain has not only been attributed to biological factors but also environmental factors. Indeed, some of these purported factors such as Ice Ages may even have extraterrestrial causes. In summary then, the individual causal factors cannot be considered in isolation as they may be part of an open, complex causal network. Bar-Yam's (2004) identification of micro-level component constraints, macro-level system constraints and environmental constraints discussed in subsection 2.3.3, I suggest, will greatly help in mapping out what causal factors should be considered as they provide a useful way of classifying the types of constraints that occur. However, the radical openness, multiple layers, heterogeneity, potential subjectivity and network-like causality must be accepted.

Secondly, there may be a variety of potential emergence relations relating to the phenomenon under investigation. For example, what is the emergent associated with the complex and highly structured global information network that is the World Wide Web – is it the information resource itself or is it the small world-like structure (Adamic 1999) which is observed when the network of interconnected URLs is viewed globally? This is a direct result of the complexity – the non-linear relations – of the system in which the emergence arises. The key issue here is to firmly establish what the particular micro-macro relation under consideration is. Further, it should be recognised that the characteristics and explanation of the emergent will be relative to the particular emergence relation under investigation. Additionally, it should be noted that while the macro-level phenomenon might be physically determined by its micro-level component parts, as the discussion of the previous paragraph illustrates, they might not be a sufficient cause.

Thirdly, epistemological factors may be real causes of emergents. Consider, for example, the social phenomenon of a church[42]. Suppose we exclude the building from the meaning of the term church and consider its more institutional or theological sense as in, for example, the Roman Catholic Church. By the core characteristics of emergence identified in subsection 2.4.3(b)(i), any given instance of a church can be considered an emergent at the social level, as it arises through social interaction, but it exists at a higher level than the individual and is physically determined by the members of the church, but not contained in any individuals. But how does the concept of church which is clearly non-physical arise? If vitalism is to be avoided, it must be physically determined, but it is difficult to attribute particular physical determinants to it. While the concept of church may physically reside in human minds or other artefacts, the concept only arises because of our reflective capacity. So epistemology, in the sense of observation and reflection, I would argue may usefully be considered a causal factor in the concept. Indeed, Sawyer (2004) even argues that social properties such as 'being a church' are emergent and have real ontological status as opposed to being epistemological in nature. Thus, our observations of phenomena, and the subsequent ideas and concepts which we generate, can give rise to new emergents. This again suggests a degree of ambiguity regarding what the 'is emergent relation' might be. In the case of 'church', are the micro-level components the congregation and body of theology or is it our individual perceptions of them? Thus, while given a non-vitalist stance, all phenomena should in principle be physically determined, in practice, the multiple layers and potentially subjective interconnectivity mean that epistemological factors appear to have a causal role.

(b) How we observe and analyse emergence

How we perceive and discuss emergence is also a key factor in the difficulty in understanding emergents. As the analysis of existing approaches in subsections 2.4.1-2.4.3 illustrates, three key factors which contribute to the difficulties can be identified. These are briefly recapped, to draw out how they might best be minimised to improve explanation of emergents.

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[42] The term church has several meanings – a building, a congregation, a theology or doctrine, a social phenomenon. All of these are a product of human interaction and by the working definition arguably emergent.

Firstly, as emergence is varyingly considered as a synchronic or diachronic process, this has considerable consequences for what constitutes the emergence relation. In the former case, it is viewed as a logical relation and the latter a dynamical one, leading to differing opinion as to what exactly constitutes the emergent relation and the emergent under consideration. For example, is the emergence relation associated with the smell of ammonia, the relation between the smell and ammonia's constituent chemicals – synchronic emergence – or are the nasal receptors also included as micro-level components – diachronic emergence? Or, alternatively, does the emergence relation hold between the potential to smell like ammonia and the constituent chemicals of ammonia?[43] Clearly, in each of these cases a different emergence is being discussed which will, therefore, affect the description of what exactly constitutes the emergent and its key characteristics such as degree of irreducibility.

Secondly, inconsistent explanations may arise due to the different epistemological viewpoints regarding emergence. To address this, I contend that within this interdisciplinary context explanation of emergents should include consideration of how differing epistemological criteria might affect perceptions of emergence. For example, Ryan (2006) highlights the impact of different scopes, which refer to the breadth of the observation of the emergence system at both macro and micro-levels, and the impact of different resolutions which encompass the scale and theoretical or conceptual model through which the observation is made. While it is reasonable to argue that scope and resolution do not affect the realisation of emergent phenomenon *per se* and therefore are not causal factors, failure to investigate a phenomenon with sufficiently wide scope or to consider the impact of our theoretical or conceptual models (resolution) can lead to misunderstanding regarding both the phenomenon and its perceived key characteristics. For example, the smell of ammonia appears irreducible to ammonia's constituent chemical components. However, when the role of nasal receptors is taken into account, the smell of ammonia can be explained. This suggests that both adoption of a sufficiently wide investigatory scope and the consideration of the impact of different scopes and resolutions will affect the coherence of descriptions of emergent phenomena – the coherence depends upon being able to state under which conditions particular key characteristics are appropriate.

Thirdly, imprecise language has been a key contributing factor to difficulties in providing universal descriptions of emergents. While the broad conceptualisation and multi-tiered

[43] These differences and their implications are considered in greater detail in Chapter 7, section 7.1(c).

typology provide conceptual structure and clarity, as highlighted in the conclusions of Chapter 5, there are still issues surrounding what exactly is meant by unpredictable, weakly irreducible or medium downward causation. Further clarity is required if we are to develop adequate descriptions which will facilitate understanding and enable further generalisation regarding emergents.

In conclusion, when considering how to improve understanding of emergence, epistemological influences, the specific 'is emergent' relation and its complex causal environment must all be addressed. Further, the terminology used in any explanation must be made explicit if it is to be used within an interdisciplinary context.

In summary, this section has provided an analysis of the review of emergence which was presented in section 2.3. The section began by considering why there are such different approaches to emergence. This identified three main reasons. Firstly, differing views regarding the nature of nature, – holist and reductionist views – give rise to differing conceptualisations. Secondly, the nature of understanding is particularly relevant to discussions regarding emergence. It indicates that as knowledge evolves we might continually need to refine our views as to what is and is not emergent. Further, despite some views that insist that emergence is ontological, all we can ever know is an epistemological reflection of the underlying ontology of an emergent. Thus, ontological and epistemological considerations both need to be considered. Thirdly, the differing rationales for exploring emergence also affect what characteristics are perceived as necessary or important.

The next subsection then considered why confusion regarding emergence continues to exist. This highlighted inconsistency in terminology and the lack of appropriate language as potential causes of confusion. Further, conceptual confusion was also in evidence. In particular, association of emergence simply with novelty or the product of a complex system, without a requirement for it to be at a macro-level, leads to confusion. Finally, differing foci regarding whether emergence is a synchronic or diachronic process – i.e. a logical or dynamical relationship – contribute further to confusion.

The third subsection analysed what conclusions might be drawn as to the nature of emergence. It began by concluding that the majority of conceptualisations consider emergence as the process whereby micro-level components give rise to novel macro-level or global properties which are not held by the micro-level components. Next, as the research is interested in the description of the instantiation of emergence, its causes and behaviour, the other claimed key characteristics identified from the preceding review were grouped and discussed within these three themes. Firstly, the key characteristics associated with the instantiation of emergents were considered in terms of the characteristics of the emergence relation: unpredictability, non-deducibility and irreducibility. Further, it was concluded that both logical and dynamic views are required and that emergents may be considered as entities as well as macro-level properties. Secondly, the key characteristics associated with the generation of emergence were identified as types of constraints (component, macro and environmental) and whether the emergence was a result of self-organisation or design.

Thirdly, the key characteristics associated with the behaviour of emergents were identified as macro-level causal powers and downward causation. It was also concluded in all three groupings of key characteristics that epistemological factors such as scope and resolution may affect how the key characteristics are perceived. The subsection concluded by briefly analysing different attempts to categorise emergence into types. Two forms of typologies were identified: those that consider different types of emergent within a specific approach to emergence, often based on different generating conditions and those that classify by conceptualisations of emergence. While the former approach is too restrictive for the purpose of this research as the typologies are conceptualisation-specific, the latter is much more interesting as such typologies offer a means of comparing and contrasting types of approaches to emergence.

The final subsection considered why understanding real-world emergents continues to prove difficult. First, the type of phenomenon that gives rise to the concept of emergence was considered. This highlighted the difficulties in establishing precisely what the emergence relation – the micro-macro relation that gives rise to the emergent – is and the causal factors which give rise to emergence. Notably, these causal factors may appear epistemological. Next, the effects of how we observe and analyse emergence were examined. This highlighted three important points: both logical and dynamical perspectives of the emergence relation must be considered as each will give rise to different perceptions of the emergence relation; differing scope and resolutions may give rise to different perceptions of the key characteristics of the emergent; and imprecise language limits the coherence of descriptions. These discussions led to the identification of three important points which should be considered when trying to explain real-world emergents within an interdisciplinary context: how different epistemological factors might affect the description; the precise emergence relation and the extent of its causal environment; and exactly what is meant by any key characteristics it identifies. Without this, I argue, any attempt at a broad explanation will be open to ambiguity and may not be coherent across disciplines and individual perceptions.

Having completed the task of this chapter, the next section summarises the chapter developments, identifying the next stage in the research process.

2.5 Summary and conclusions regarding emergence

In this chapter, the different approaches to emergence found in the extensive literature on the subject were explored with the aim of identifying why different approaches developed and what the consequences of these differing views of emergence are for this research. Three general sets of approaches were identified – emergence as ontological novelty, epistemological novelty and the product of a complex system. The first set, which views emergence as ontological novelty, was further subdivided into two, based on what constitutes an emergent – novel properties and novel entities and rules respectively. The latter subset was further divided into hierarchies, macro-level causal power and downward causation. At the core of all of these approaches is the idea that these macro-level properties are irreducible, to varying degrees, to their lower-level constituent parts. The second set of approaches views emergence as epistemological novelty. This was further subdivided into three: phenomenological; relative to theory or knowledge; and model change. At the core of these approaches is the fact that our conceptualisation of an emergent depends to a large extent on our perceptions and existing knowledge. However, the third subset suggested, in some cases at least, the need to employ, or preference for, a new model arises from the capabilities of the 'system' in which the emergence occurs. In this epistemological novelty view of emergence, non-deducibility and unpredictability were generally considered the key characteristics associated with emergence. The third set of approaches views emergence as the product of a complex system. These are not in general interested in epistemological or ontological properties of emergents; rather they concentrate on investigation of the mechanics or generation of macro-level properties, which result from non-linear interactions. This view considers emergence as macro-level patterns – structure or processes – which extend in time and space, arising from non-linear relationships between component parts. Although increasingly, the effect of macro-level and environmental constraints are also acknowledged. Thus, these 'product of complex system' approaches are concerned with how emergents are generated rather than their ontological or epistemological status.

Analysis concluded that the core interest in the concept of emergence arises from the observation that some macro-level phenomena – emergents – appear to arise from interconnection of micro-level components, but they cannot be fully understood or explained in terms of the micro-level components. As the review of section 2.3 illustrated, this has led to both philosophical interest in the nature of emergents and their role in explanation, and to the adoption of the concept of emergence by the complex systems community to describe, and investigate, the product of complex interactions. These differing interests in the concepts, combined with the range of problem domains to which the concept is applied, has resulted in a variety of different, often apparently conflicting, approaches to the concept of emergence, none of which are uniquely privileged (Silberstein 2002). While the different approaches are not necessarily incompatible – rather they arise because of differing investigative questions and philosophical stances – the confusion, lack of agreement on a definition of emergence and the plethora of approaches indicate that deeper understanding of the concept of emergence is required.

Part of the confusion arises from imprecise or overlapping use of language. Different purposes of employing the concept of emergence and philosophical stances, which tend to be discipline-dependent, add significantly to the confusion. Care with language and making explicit underlying assumptions such as investigative purpose, discipline-dependencies and philosophical stance should help reduce confusion, allow commonalities to be identified and facilitate insights from the various approaches to be extrapolated appropriately across disciplines, problem domains and purposes – an essential step if understanding of emergence is to be improved. The use of non-phenomenological language will help greatly, as will clarity in the scope, scale and resolution being considered in a given context.

Philosophical differences have proven particularly problematic. As our observations and theorising are epistemological in nature, this should be the starting point of any investigation of emergence, while bearing in mind the possibility that the epistemological emergence is a reflection of ontological reality. Further, while the reductionist-holist debate remains unresolved, an approach such as Bedau's which admits a range of emergents from strong irreducible type emergents (holist) to weak reducible in principle emergents (non-simple reductionist) is useful as it provides a framework for further exploration of the concept and investigation of whether strong emergents are possible.

Different approaches to the process of emergence itself also add significantly to the confusion. If emergence is to be fully understood, both how emergents evolve and persist over time – diachronic emergence – and how emergents are instantiated at a given time – synchronic emergence – must be addressed. Again, which particular emergence relation is being investigated must be made explicit.

While the ongoing disagreement and confusion may be a result of an essential fuzziness of the concept – as evidenced by the difficulties in agreeing on examples of emergence – the following core features and broad conclusions may be extracted. Firstly, the arising of novel macro-level properties – emergents – from micro-level components appears to be a core property of emergence, although the exact nature of this macro-micro relation is debated. In particular, there is still an ongoing debate as to whether emergence is ontological or epistemological in nature. Secondly, key but not necessarily defining characteristics can be identified. Irreducibility, unpredictability, non-deducibility and surprise are all characteristics associated with the emergence relation (the micro-macro relation). Further, this relation may be considered a dynamical or a logical one. Key characteristics associated with the generation of emergents are types of constraints (component, macro and environmental) and whether the emergence is a result of self-organisation or design. The behaviour of emergents might be characterised as displaying macro-level causal powers or downward causation. Thirdly, epistemological factors such as scope and resolution may affect how these key characteristics are perceived. Finally, while there is no universally accepted or applicable categorisation of types of emergence, typologies that classify by conceptualisations of emergence offer an interesting and potentially useful means of comparing and contrasting conceptualisation of emergence.

Finally, consideration of why understanding real-world emergent phenomena continues to prove difficult led to identification of three key reasons. Firstly, the ontology of emergents is difficult to establish. In particular, due to inherent complexity, there is a difficulty in establishing precisely what the emergence relation – the micro-macro relation that gives rise to the emergent – is and the causal factors which give rise to emergence. Further, some of the ontological causal factors may actually appear epistemological. Secondly epistemological factors relating to how we observe and analyse emergence can influence the applicability of explanations across the differing disciplinary perspectives and philosophical stances. Both logical and dynamical perspectives of the emergence relation must be considered as each will give rise to different perceptions of the emergence relation. Further, differing scope and resolutions may give rise to different perceptions of the key characteristics of the emergent; and imprecise language limits the coherence of descriptions.

Having undertaken an extensive review and analysis of the extant literature on emergence the research design is considered in the next chapter.

Chapter 3 Research Design

Having provided a summary of the research in Chapter 1 and undertaken an extensive review of the discourse on emergence in Chapter 2, attention is now turned to the design of the research. Following Patton (2002) the research design is developed from the research problem context. As outlined in Chapter 1, section 1.2 the research problem is – *how to improve understanding of emergence, given the wide variety of perceptions and conflict regarding emergence.* The design process, summarised in Figure 3-1 below, was iterative, evolving as the literature review and peer discussions developed.

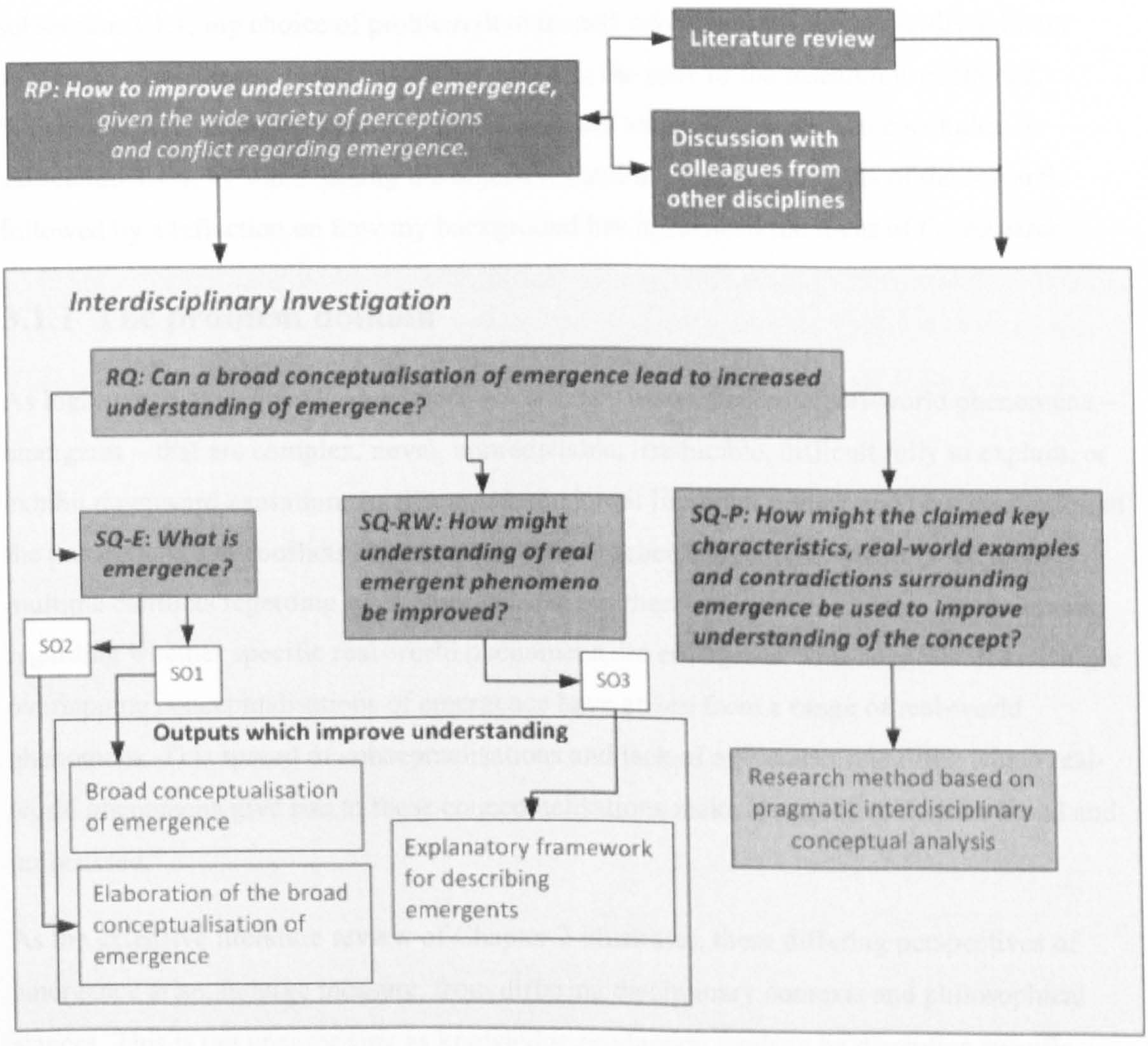

Figure 3-1: Summary of the research design

The chapter proceeds as follows. First, section 3.1 describes the focus of this interdisciplinary investigation, considering the broad problem domain that has been adopted and its pragmatic and interdisciplinary solution which gives rise to the three outputs – the broad conceptualisation of emergence, its elaboration and the explanatory framework for describing emergents. Next, in section 3.2, the method used to achieve the research objectives is described. The chapter ends, in section 3.3, with a brief summary or the research design.

3.1 Focus of the research

As the title of this thesis suggests, the focus of this research is concerned with improving understanding of emergence using a pragmatic interdisciplinary approach. This section considers this pragmatic interdisciplinary focus and how it leads to new understanding regarding emergence, reflecting on the factors which have influenced this design. Firstly, in subsection 3.1.1, my choice of problem domain and why this leads to an interdisciplinary approach is considered. Next, in subsection 3.1.2, the crux of the research is explained. Subsection 3.1.3 then considers the broad approach adopted. The section concludes, in subsection 3.1.4, by summarising the objectives and the resulting outputs of the research followed by a reflection on how my background has influenced the focus of the research.

3.1.1 The problem domain

As highlighted in chapter 1, emergence is variously associated with real-world phenomena – emergents – that are complex, novel, unpredictable, irreducible, difficult fully to explain, or exhibit downward causation. As discussed, the initial literature review and peer discussion of the perceptions and conflicts associated with emergence suggest that not only are there multiple conflicts regarding what emergence is but there is also considerable disagreement regarding whether specific real-world phenomena are emergents. This suggests that multiple overlapping conceptualisations of emergence have arisen from a range of real-world phenomena. This spread of conceptualisations and lack of agreement regarding which real-world phenomena give rise to these conceptualisations make the problem domain broad and unfocussed.

As the extensive literature review of Chapter 2 illustrates, these differing perspectives of emergence arise, in large measure, from differing disciplinary contexts and philosophical stances. This is not unsurprising as knowledge production tends to be discipline specific (Becher and Trowler 2001). According to Chettiparamb (2007, p3), this is because of what Aram (2004, p380) terms "[disciplinary] thought domains – quasi-stable, partially integrated, semi-autonomous intellectual conveniences – consisting of problems, theories, and methods of investigation" which restrict the problems that are of interest, how they are perceived and explicated, and the methods used to address them. Further, disciplines themselves are not necessarily cohesive knowledge domains, with fragmentation often occurring as a result of divisions of ideology, epistemology, methodology or theory (Dogan and Pahre 1990, cited by Chettiparamb 2007). The influence of ideology is clearly in evidence in the differing philosophical stances adopted with respect to emergence which transcend disciplinary differences. As is shown in Chapter 2, this is a significant factor in the differing perceptions of emergence.

How then to address the research problem *RP – how to improve understanding of emergence, given the wide variety of perceptions and conflict regarding emergence.* The common approach when dealing with a complex problem that is proving resistant is to drill down on one particular, potentially idealised, aspect of the problem domain to explore whether greater understanding of the chosen aspect can be achieved. So, one potential way forward would be to aim to develop deeper understanding of emergence within one particular perspective. While the majority of existing approaches have attempted this, as discussed in Chapter 1, this has not led to a generally accepted definition or explanation of emergence. Narrowing of the problem domain can be problematic for two reasons. Firstly, where the problem is complex – i.e. the result of several interrelated factors, failure to take account of all the factors can lead to very limited understanding that does not relate well to the real world. Secondly, I would argue that narrowing of the focus actually circumvents the problem of what emergence actually is. Thus, while my initial intention had been to focus my research on a narrow understanding of emergence, I would argue that a wider and more innovative approach is required. A broad approach is, therefore, adopted where as wide as possible a perspective on what emergence might be is considered when designing the research.

This choice of including input from these different disciplinary perspectives and philosophical stances makes the research interdisciplinary in nature. This idea that we can improve understanding of difficult problems by considering different perspectives and tools from differing disciplines is a key driver for interdisciplinary research (Committee on Facilitating Interdisciplinary Research and Committee on Science 2004). According to Chettiparamb (2007), Dogan and Pahre's (1990) study illustrates how value arises from interdisciplinary 'hybrid zones' where innovation occurs as participants look beyond their disciplinary thought domain, applying fresh insight afforded by the intersection of perspectives to identify gaps and novel solutions. Thus, interdisciplinary approaches seek to apply innovative approaches and combinations of knowledge to move beyond existing disciplinary thought domains.

This interdisciplinary choice follows not only from the broad and unfocussed problem domain but also my own interdisciplinary background, where as an experienced applied researcher, I work in partnership with academics from a number of departments.[44] Such discussions not only help to reveal the differences in understanding regarding varying concepts and why they have arisen but also, as Dogan and Pahre (1990, cited in Chettiparamb 2007) advocate, they offer a powerful means of developing innovative solutions to socio-technical problems.

3.1.2 What the research is about

Having explained the rationale behind the adoption of a broad multi-disciplinary problem domain, this subsection considers the broad strategy and the implications that the interdisciplinary nature will have on the research, concluding with an explanation of the broad thesis which the research addresses.

(a) The broad strategy

The research, then, is interdisciplinary in nature. According to Klein (2000), while interdisciplinary research is a highly complex hybrid activity, it is concerned with two broad types of activity – 'borrowing', where concepts from one discipline are adopted by another and 'problem solving', where different disciplinary skills and/or knowledge are brought together to solve complex real-world problems. Borrowing tends to lead to new knowledge or techniques within a given discipline rather than synthesis of new knowledge, applicable across multiple disciplines. For example, Klein discusses how chaos theory, from mathematics, has been borrowed by differing disciplines to model, for example, turbulence by engineers and expose the ideological underpinnings of traditional ideas of order by literature theorists. Problem solving or problem-driven approaches, on the other hand, tend to be concerned with complex real-world problems that are proving resistant to disciplinary understanding. As Brewer (1999, p328) observes, in problem-driven approaches "[p]roblems designate theory and methods, not the reverse, in sharp contrast to discipline-based and curiosity-driven inquiry." Mode 2 type knowledge production processes are employed where new knowledge is developed through trying to resolve a particular real-world problem in situ and without the confines of specific disciplinary ways of thinking or practice

[44] Further, the lack of existing experience in emergence within Computer and Information Sciences (CIS) necessitated that colleagues from outwith CIS be included in the informed peer review process.

(Gibbons et al. 1994). Technological innovation is a good example of this form of interdisciplinarity.

In this research a variation on an interdisciplinary problem-solving approach is adopted. This is principally because, as discussed in subsection 3.1.1, I am concerned with addressing a broad problem – what is emergence. This conceptual problem could arise from different disciplinary interpretations of one core phenomenon of emergence or it could simply be a result of different phenomena having the same label. However, this problem, while clearly influenced by differing disciplines, is not itself a discipline specific problem – i.e. the problem of what emergence is is influenced by but transcends the different disciplines. Thus, in a sense I am addressing a real-world problem although it is conceptual in nature and hence my approach is a variation on typical interdisciplinary problem-driven approaches as such problems are not, in general, conceptual in nature.

(b) Interdisciplinary knowledge

The types of outputs that interdisciplinary research can produce and which fit best within the context of this conceptual problem driven research are considered below.

As Salter and Hearm (1997) identify, outputs of interdisciplinary research can be applied or conceptual. Applied outputs take the form of new methods or tools which can be used to explore and resolve real-world problems from an interdisciplinary perspective. For example, a new way of manufacturing a highly complex component or a new initiative for tackling climate change might be typical outputs of problem-driven interdisciplinary investigation. These tools are claimed to be discipline independent, usable by a range of different disciplinary practitioners and researchers. Generally, conceptual outputs take the form of new disciplinary knowledge or theories and are more normally associated with borrowing approaches. The new understanding of turbulence within engineering and of the ideological underpinnings of traditional ideas of order within literary theory, mentioned above in subsection (a), are prime examples of this.

Given my applied research experience, I am interested in developing outputs which will provide insight regarding real-world problems rather than simply undertaking an intellectual exercise. So, while this research is clearly conceptual in nature, my interest is in developing conceptual tools which can be used to improve understanding of the phenomenon of emergence and of the real-world emergent phenomena which give rise to the concept. While the idea of a conceptual tool may not appear overly practical, my experience of interdisciplinary discussion of emergence clearly illustrates the needs for some kind of tool for enabling translation between different perspectives or for mediating shared understanding.

As the preceding discussion of subsection (a) touches upon, interdisciplinary research does not necessarily lead to interdisciplinary outputs. Thus, the new knowledge or tools produced in this research could be discipline specific or they could, in principle at least, transcend disciplinary boundaries. Thus, the research could aim to increase discipline-specific conceptual understanding of emergence or it could try to develop conceptual understanding which transcends disciplinary divides. As I have argued in subsection (a), the problem being addressed here transcends the differing disciplines and philosophical stances. This strongly suggests that the new knowledge to be produced should itself attempt to transcend the differing disciplines and philosophical stances – i.e. the aim should be to produce new transdisciplinary[45] understanding of emergence. However, such an approach is not without problems.

Firstly, it has been questioned whether truly transdisciplinary knowledge can be developed. As discussed previously, one of the principles behind interdisciplinary research is that a new transdisciplinary understanding can be developed through exposure to different perspectives and negotiation of meaning and understanding. As Stember (1991) argues, this encompasses new epistemological development which attempts to integrate disciplinary knowledge to the extent that disciplinary aspects disappear. However, development of a new unified epistemology does not always result. For example, as Salter and Hearm (1997, p12) warn, there is a danger that such attempts at transdisciplinary outputs simply result in outputs which "reflect a grouping of different studies with very little in common." This may be a result of inability to create a shared conceptual language.

Secondly, even when there is a will to develop shared meaning, the differing researchers' conceptual baggage and what Becher and Trowler term (2001) ways of thinking and practice may make it difficult to sufficiently step out of individual thought domain to develop transdisciplinary knowledge. The language different disciplines use can be particularly problematic when attempting to develop shared meaning or abstraction as the same terminology or metaphors can be employed by different disciplines to convey different

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[45] Transdisciplinary is used to signify knowledge, tools or other outputs that are applicable across a range of disciplines where as interdisciplinary is a more general term signifying the influence of multiple disciplines.

things. For example, the term complexity theory is often used to refer to the theories relating to complex systems. However, within Computing Science, the term complexity theory refers to a branch of computational theory which is concerned with the classification of problems according to their inherent difficulty. Further, as Wear (1999) discusses, while metaphors are frequently used within a discipline to convey a wealth of understanding, the full breadth of imagery which they convey may be invisible to someone outside the community. For example, according to Wear, within the biological sciences the term 'niche' invokes powerful imagery which conveys identifiable components of ecosystems, whereas to an economist, it implies something that is relatively incidental to the working of the economy as a whole. Thus, common understanding, whether it is conceptual or linguistic, cannot be relied upon. Further, the disciplinary training of researchers often includes norms and assumptions, which while shared tacitly within the disciplinary community are never made explicit (Becher and Trowler 2001).

Thirdly, the usefulness of transdisciplinary knowledge has also been questioned. One issue here is that there may be little common ground in terms of concepts, methods and language between different disciplines. Thus, for something to be understood across such a range of disciplines, the knowledge must be abstracted to a high degree, encompassing the few shared high-level concepts and subconcepts. As Checkland (1999) argues, such abstractions, however, may be so general to be of little practical value in furthering understanding of real-world problems. Finally, as Salter and Hearm (Salter and Hearn 1997) note, transdisciplinary research may also fail to make its mark simply because of extant disciplinary bias.

Alternatively, the research could seek to develop a new 'interdisciplinary informed' but 'discipline-focused' understanding of emergence. However, this too is not without problems. Firstly, the most significant issue is that a focus on developing new disciplinary understanding of emergence would, I contend, be counter to the aim of trying to address the problem of what emergence is. This is because, as I have argued above, the problem transcends the differing disciplines and philosophical stances. Secondly, there may be a tendency from other disciplines to simply reject the developments as not applicable in their domain. Such rejection can arise because the concepts or language used is unfamiliar or does not make sense within their disciplinary context due to different terminology and epistemologies. Further, it may simply, as with transdisciplinary knowledge, be dismissed because of bias.

The preceding discussion highlights both the advantages and disadvantages of disciplinary and transdisciplinary knowledge. The problems of limited abstraction and disciplinary language could be alleviated by attempting to integrate the disciplines to the extent that disciplinarity disappears, giving rise to a unified investigation. Indeed, Klein (1996) considers the emergence of new disciplines, with their own language and conceptual understanding, a measure of success. The new interdisciplinary Web Science movement is a prime example (Hendler et al. 2008). However, not only is this infeasible within the resource constraints of a PhD, but it could also, I contend, restrict the ongoing creativity afforded by leveraging different disciplinary knowledge and thought domains. As Boulding (1956) argues in his seminal paper on General System Theory, it is important that interdisciplinary (systems) theories are actually utilised within different disciplinary contexts in order to explore what added insight can be generated within the disciplines themselves through exposure of differing contexts. This, therefore, suggests that the new transdisciplinary understanding should not be so embedded in a new unified thought domain that it cannot be utilised within the contributing disciplines. So, rather than choose between producing high-level transdisciplinary knowledge and interdisciplinary informed but discipline specific knowledge, as discussed in the next subsection, this research focuses on developing both transdisciplinary and disciplinary outputs.

(c) The broad thesis

The question then is how to address the interdisciplinary problem of what emergence is in a productive way. Wilson's (1998, p8) observation that interdisciplinary approaches combine knowledge from across disciplines to create "a common groundwork of explanation", cited in the Committee on Facilitating Interdisciplinary Research (2004, p29) report on interdisciplinary research, suggests a useful way forward. This view does not necessarily imply that a definitive transdisciplinary definition or scientific explanation is produced; rather it simply encapsulates the idea that an epistemological framework can be synthesised which can be used to further develop discipline or transdisciplinary understanding. The question then is what form should this "common groundwork of explanation" take?

Rather than aiming to develop specific disciplinary or transdisciplinary understanding, the solution adopted is to embrace and make explicit these tensions within an overall epistemological framework, because as Klein (1996, p2) argues, "disciplinarity and interdisciplinarity are productive tensions in a dynamic of supplement, complement and critique." This is achieved by adopting a pragmatic approach where the broad conceptualisation of the principle research question[46] is designed to be an epistemological bridge (Chettiparamb 2007) which combines elements of abstraction, translation and explicit disciplinary and philosophical stance related understanding. This is consistent with Chettiparamb's (2007, p23) observation that epistemological bridges such as General Systems Theory necessarily contain both disciplinary issues and integrated meta-level concerns which coexist within the epistemological bridge.

Thus, my thesis is that if the extensive extant emergence discourse is a result of some core, but potentially fuzzy real-world phenomenon[47] then it may be possible to combine abstraction of certain core characteristics regarding emergence which are applicable across differing conceptualisations, disciplines and philosophical stances together with translation and key aspects of different perspectives to provide an interdisciplinary conceptual framework to improve understanding of emergence – i.e. by adopting such a broad interdisciplinary approach it might be possible to improve understanding of what emergence is both across and within relevant disciplines and philosophical stances.

This choice of developing the broad conceptualisation as an epistemological framework which supports bridging follows from the problem domain, the nature of disciplinarity and interdisciplinarity and a wish to develop something that will be useful to researchers or practitioners from differing disciplinary contexts. By focusing on developing an epistemological framework which can act as a bridge rather than simply investigating the differing perceptions of emergence, my objective is to be able to develop an overarching conceptual framework that can be more readily presented and, I would argue, discussed, understood and utilised across multiple disciplinary contexts and philosophical stances than if I simply exposed individual perceptions of emergence, lacking any epistemological bridging structure. If successful, this, I argue, will enable the different extant disciplinary knowledge regarding emergence to be better leveraged.

Further, this approach means that I am aiming to reduce any bias towards my own individual perception of emergence from the research. Total removal of bias will of course be impossible given that our understanding is inevitably based on disciplinary perspectives and

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[46] *RQ – Can a broad conceptualisation of emergence lead to increased understanding of emergence?*

[47] i.e. The emergence discourse has not arisen because similar terminology has been employed to discuss a range of different unconnected phenomena.

philosophical stances. However, no extant disciplinary view on emergence is considered privileged. While this normal scientific practice might be deemed an odd approach within the social sciences, I would contend that this approach of attempting to remove the researcher from the equation will not restrict the applicability of research findings to the scientific community alone provided that (i) the rationale for the broad conceptualisation approach is explained and (ii) it is made clear how the broad conceptualisation relates to specific disciplinary or individual perceptions.

The link with Chettiparamb's (2007) idea of an epistemological bridge, which she developed through her discussion of Boulding (1956), came later, providing a degree of confirmation of the validity of this approach. It must be noted, however, that while these broad design criteria for the broad conceptualisation are compatible with the above epistemological aims of General Systems Theory, it is not the intention that the broad conceptualisation be a form of General Systems Theory. To do so would be to make a particular thought domain dominant. Indeed, this would be particularly problematic in this case as complex systems – one of the main areas interested in emergence – is arguably highly related to General Systems Theory. Precisely why this is not a General Systems Theory approach is discussed in subsection 3.1.3(c) below.

The objective of the broad conceptualisation can then be said to be to provide a broad conceptual framework which will act as an epistemological bridge enabling researchers and practitioners from different disciplinary perspectives and philosophical stances to increase understanding of emergence. In broad terms then, this research is concerned with increasing understanding of emergence through development of a transdisciplinary epistemological bridge and conceptual tools based around a broad conceptualisation of emergence. The next subsection considers how this is achieved.

3.1.3 The broad approach

The research is then about increasing interdisciplinary understanding of emergence through a broad conceptualisation which acts as an epistemological bridge. The outputs will form conceptual tools which provide a means of increasing both transdisciplinary and disciplinary understanding of the concept of emergence (*SQ-E*) and real-world emergents (*SQ-RW*). What is meant by increasing understanding within the context of this research and how the epistemological bridge of the broad conceptualisation is itself conceptualised and its relation to General Systems Theory are considered in turn below.

(a) Increasing understanding

As the principal research question captures, the focus of the research is on increasing understanding. By this I mean that I am not seeking an ultimate all encompassing explanation of emergence; rather my aim is to make inroads into the difficult problem of how emergence might be usefully understood. This therefore limits the scope of what I am aiming to achieve – a vital step, I argue, given the extent of disagreement regarding emergence. Further, despite my scientific background, I am focussing on understanding rather than a more specific aim such as scientific explanation. This is because, given the extent of the differing views of emergence and the disagreements regarding whether specific real-world phenomena are emergent, I would argue that it is unlikely that a generally agreed scientific explanation of emergence can be achieved at present. This lack of agreement regarding whether specific real-world phenomena are emergent or not is particularly problematic for attempts at scientific explanation as one must question whether different researchers are even discussing the same phenomenon when they use the term emergence. This issue was clearly in evidence during my discussions with different disciplinary colleagues.

What then is meant by increasing understanding within the context of this research? According to Miles and Huberman (1994), research to increase understanding might vary from exploratory research designed to better describe the object under investigation to more explanatory approaches which seek to address how objects behave in a certain way or why they have certain characteristics. In general, the choice of approach derives from the current level of knowledge regarding the object under investigation. More explanatory type approaches clearly bring more benefit.

The research has two foci for improving understanding – whether a broad conceptualisation can improve understanding of emergence *(RQ)* and whether understanding of real-world emergents can be improved *(SQ-RW)*. Based on the results of the literature review, what might equate to increase understanding for each is examined below.

(i) Increasing understanding of emergence

As discussed earlier, the problem the broad conceptualisation is designed to address is a conceptual one relating to what emergence is, given the wide and varying conceptualisations of emergence. Unfortunately, as the extensive literature review of Chapter 2 illustrates there is as yet no agreed description of emergence or what constitutes an emergent. Thus, I argue, a descriptive approach is potentially useful and indeed necessary if a common ground for discussing emergence is to be achieved. However, as discussed earlier, the aim is to make inroads and help develop new insights. So, I contend that the broad conceptualisation can be said to improve understanding of the concept of emergence if it can:

(i) Provide a coherent and plausible description of the broad concept of emergence;
(ii) Provide an explanation for at least one of the key conflicts surrounding understanding of emergence;
(iii) Facilitate disciplinary and interdisciplinary analytical discussion of emergence.

(ii) Increasing understanding of real-world emergents

The literature review and analysis of Chapter 2 reveals two key problems relating to understanding real-world emergents. Firstly, there is ongoing dispute regarding whether a given real-world phenomenon is emergent of not. Secondly, there is the issue of clarifying exactly what is the emergent under investigation. This arises because as the review identifies, the core characteristic associated with a phenomenon being emergent is that there is a relational characteristic between micro-level components and macro-level features. So, much of the disagreement pertaining to whether a given phenomenon is emergent arises because of differing views regarding what the relevant micro-level and macro-level components are.

Thus, I contend that understanding of real-world emergent phenomena can be said to be increased if a conceptual tool can be developed that can:

(i) Be used to establish whether a real-world phenomenon is emergent;
(ii) Clarify exactly what the 'is emergent' relation is.

The broad conceptualisation could be used to establish whether a real-world phenomenon is emergent by comparing a description of the phenomenon with the core characteristics and relevant key characteristics relating to a given conceptualisation. However, if we are to explore, for example, under which conceptualisations a phenomenon is emergent in order to leverage the appropriate thought domains to improve understanding, then arguably a description that covers the full range of core and key characteristics that may pertain to an emergent within the overall broad conceptualisation would be more useful. This then, I contend, also may be said to provide a more comprehensive description of a real-world emergent than a description arising out of a single thought domain specific conceptualisation. Further, as the analysis of Chapter 2, section 2.4 illustrates, these core and key characteristics can be split into characteristics pertaining to the instantiation of an emergent, how an emergent phenomenon arises and how it behaves. Such a description has the added advantage that it is explanatory in nature as it addresses 'how', therefore offering the potential of enabling more analytical explanatory conclusions to be drawn (Miles and Huberman 1994).

Thus I contend that understanding of real-world emergent phenomena can be said to be increased if a conceptual tool can be developed that:

(iii) Includes the full range of core and key characteristics relating to the instantiation, generation and behaviour.

Whether understanding of the concept of emergence or real-world emergents is actually increased through a given explanatory description is a subjective judgement. The research therefore focuses on showing plausibility and potential usefulness of the broad conceptualisation and tools developed.

(b) Conceptualising the broad conceptualisation of emergence

As discussed in subsection (a)(i) above, for the broad conceptualisation to be successful it should facilitate disciplinary and interdisciplinary conceptual analysis of emergence. Further, as explained in subsection 3.1.2(c), this should be achieved through an epistemological framework which supports abstraction, translation and distinct disciplinary knowledge. The approach I adopt is to split the epistemological framework into two components: an overarching 'transdisciplinary component' which contains the transdisciplinary knowledge that can be abstracted from the different approaches to emergence and a more detailed 'thought domains component' which contains thought domain specific conceptual knowledge. While the approach is driven by the nature of interdisciplinary knowledge and discourse, as the following discussion illustrates, my conceptualisation of the problem and its solution is strongly influenced by my mathematical background.

Conceptualisations are concerned with representing our interpretations of the real-world. Unless they are primitive or atomic, concepts have some kind of conceptual structure (Laurence and Margolis 1999) which consists of interrelated subconcepts and relations to other concepts. The broad conceptualisation can therefore be thought of as a 'structured superset' which contains all the concepts and subconcepts relating to the broad problem domain of what emergence is. This, I split into two components – a 'transdisciplinary component' and a disciplinary or 'thought domains component'. The diagram of Figure 3-2 below illustrates the relationship between the two components of the epistemological framework and their sub-components.

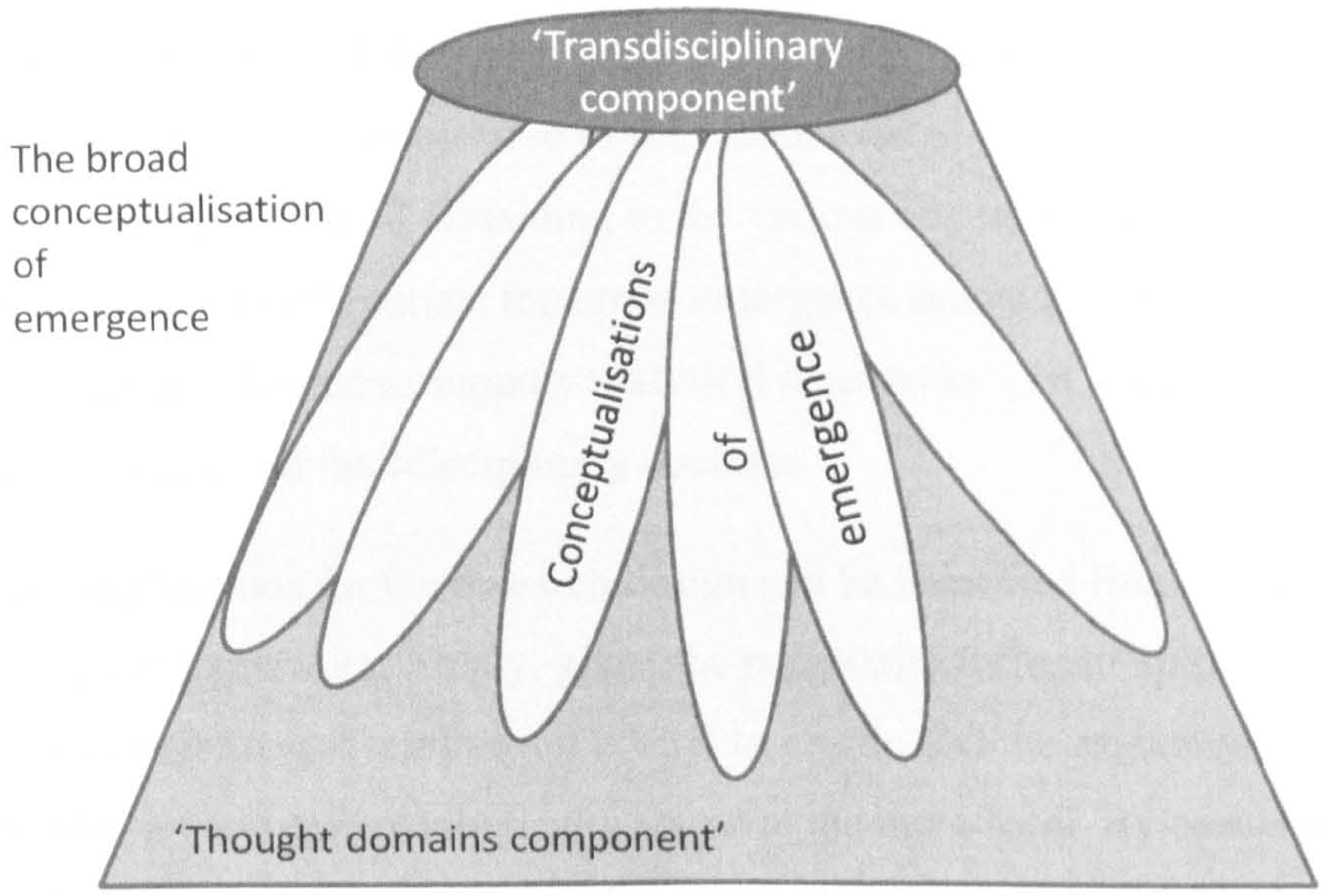

Figure 3-2: Overview of the components of the broad conceptualisation of emergence

The overarching 'transdisciplinary component' of Figure 3-2 contains the core components which the individual conceptualisations share – i.e. the transdisciplinary abstractions of the epistemological bridge. The 'thought domains component' of Figure 3-2 contains the multiple conceptualisations relating to differing conceptualisations of emergence and represents the 'disciplinary component' of the epistemological framework. The term 'thought domains component' is used rather than 'disciplinary component' because, as discussed in subsection 3.1.1, the differing perceptions are influenced by discipline and philosophical stance and not by discipline alone. As Figure 3-2 captures, the various conceptualisations of the thought domain component overlap to an extent and it is from this common area of overlap that the abstractions of the transdisciplinary component can be synthesised.

Swartz's (1997) advice of not trying to define everything about a concept at the first stage of analysis seems particularly apt to this context given the ongoing definitional problem. The development of the epistemological framework is, therefore, split into two parts – the broad conceptualisation and its elaboration. The objective of the broad conceptualisation is to provide a high-level abstraction of what emergence is. As this transdisciplinary component represents the common intersection of understanding regarding emergence, as Figure 3-2 attempts to capture, it therefore bounds what is considered emergence within the context of this research. That is, if a real-world phenomenon does not fit the broad conceptualisation then it is not considered emergent under any of the differing conceptualisations of emergence. If there are no such core characteristics then this approach will not work. However, as the analysis of the literature presented in Chapter 2, section 2.4 reveals, core characteristics can be identified; however, there are no sufficient characteristics, making emergence a fuzzy concept. The objective of the elaboration of the broad conceptualisation is to provide the conceptual detail pertaining to the various conceptualisations of emergence. It therefore will span and differentiate the broad emergence domain. Further, as discussed in subsection 3.1.3(a), it will need to support analytical discussion – i.e. conceptual analysis – within both disciplinary and interdisciplinary contexts.

Two important implications for the research design can be identified from this choice of two-part epistemological framework. Firstly, given the potentially different epistemologies that exist within the contributing disciplines, it is vital to ensure that the epistemological bridge developed is coherent and epistemologically sound at the meta-level. By epistemologically sound I mean that the conceptualisation makes sense at the meta-epistemological level, using existing meta-concepts and fitting in with our overall understanding of concepts *per se*. Without this meta-level 'sense', it is unlikely that sound analytical discourse across the conceptualisations can be facilitated. Thus, in the elaboration of emergence both the links between the subconcepts and the meta-structure of the concept itself – the 'type' of concept – should be valid – i.e. should make sense. This implication was again originally influenced by mathematical thinking as the need for a sound epistemology was conceived in terms of a need to be explicit about the topological structure of the emergence superset. Secondly, these concepts, subconcepts and their relationships are identified in the literature review of Chapter 2 – i.e. they are the core and key characteristics and their relationships. Such a broad conceptualisation, therefore, also spans the full range of the broad problem conceptual domain. Thus, while the broad conceptualisation is informed by applying the research subquestion *SQ-E – what is emergence* –to the various differing conceptualisations, it also itself provides an answer to the question.

(c) Relation of broad strategy to General Systems Theory

As introduced in Chapter 2, section 2.1 General Systems Theory is concerned with investigating and managing complex real-world systems from multiple disciplinary perspectives within one overall systems framework. The general aim, as Boulding (1956) observes, is to develop new systems-level scientific understanding which transcends but builds on different disciplinary perspectives. The epistemological bridge approach adopted in this research therefore shares the epistemological aims of General Systems Theory.

However, I contend that my approach is not a General Systems Theory approach for two reasons.

Firstly, General Systems Theory is put forward as a "skeleton for science" (Boulding 1956), offering a new non-reductionist paradigm for understanding the world around us. I make no such strong grand assertion regarding the broad epistemological bridge approach; rather it is simply a conceptual tool designed to address a specific problem. Further, as discussed in subsection 3.1.3(a) above, it is concerned with conceptual rather than scientific understanding.

Secondly, as Richardson (2004) observes, a major objective of General Systems Theory and associated systems theories is to facilitate communication between fields of interest by providing a common language with which to discuss 'systems problems'. This was based on the observation that these systems seemed to share certain similar meta-level features (von Bertalanffy 1950) such as the '*the whole is greater than the sum of the parts*', *emergents* and more recently within Complex Systems approaches *self-organisation*. The common language, if indeed it is that, which I am creating is not concerned with meta-level systems theoretic features, rather it is simply the minimum shared subconcepts and relations within a given concept. Terms like – *macro-level properties (emergents) which are not manifest in individual micro-level components in isolation* – appear in the common language only because the concept under discussion arguably shares many characteristics relating to systems type approaches. Further, the common language created is quite limited, because as discussed above in subsection 3.1.2(c) above it is necessarily the areas of common ground. Thus, what I am concerned with primarily is a framework that allows translation between different disciplinary conceptual languages where appropriate and simply exposure of the disciplinary concepts and languages where that is not appropriate.

Thus my approach is not a General Systems Theory approach, although I acknowledge my prior exposure to interdisciplinary working and complex systems based approaches has influenced my line of thinking.

3.1.4 Objectives, outputs and reflections

Having described the research focus in the preceding subsections, this subsection draws the discussion on focus to a close. First, the objectives of the research and the resulting outputs are presented. This is followed by a reflection on the impact of my background on the research focus.

(a) Objectives and outputs

Drawing together the preceding discussions of the research focus, the objective of the research can be summarised as – ***to develop a broad conceptual framework which will act as an epistemological bridge, enabling researchers and practitioners from different disciplinary perspectives and philosophical stances to increase understanding of emergence within both interdisciplinary and disciplinary contexts (O).*** This is to be realised through development of a broad conceptualisation of emergence and related conceptual tools.

Three specific subobjectives are set to focus the conceptual development:

SO1: To develop an overarching transdisciplinary conceptualisation of emergence that integrates and bounds the broad emergence domain;

SO2: To develop an elaboration of the broad conceptualisation that (i) spans and differentiates the broad emergence domain and (ii) supports analytical discussion within both interdisciplinary and disciplinary contexts;

SO3: To develop a tool for generating an explanatory description of real-world emergents that can be used to (i) establish whether a real-world phenomenon is emergent; (ii) clarify exactly what the 'is emergent' relation is; and (iii) describe the full range of core and key characteristics relating to the instantiation, generation and behaviour of an emergent.

As Figure 3-1, p92 summarises these objectives arise from the broad problem, the research questions and the interdisciplinary issues discussed within this section. In particular, *SQ-E – what is emergence* – leads to two subobjectives SO1 and SO2. These two subobjectives capture the need, discussed in subsection 3.1.3, to consider the epistemological framework in terms of two components - an overarching component which integrates, bounds and abstracts existing approaches to emergence to develop a transdisciplinary conceptualisation of emergence and a differentiating component which accommodates the various approaches and conceptualisations of emergence. SQ-RW – *how might understanding of real-world emergent phenomena be improved*– leads directly *to SO3.*

As Figure 3-1, p92 illustrates, these objectives are each realised by a different conceptual proposal. The broad framework and its elaboration together answer *SQ-E – what is emergence* – providing both an interdisciplinary conceptualisation and a conceptual tool that can be used to support interdisciplinary analysis of emergence. The explanatory framework for describing emergents answers *SQ-RW – how might understanding or real-world emergent phenomena be improved* – and again is a practical conceptual tool which is compatible with the broad conceptualisation approach. As is discussed in section 3.2, the method used to develop these conceptual proposals is based on *SQ-P – how might the claimed key characteristics, real-world examples and contradictions surrounding emergence be used to improve understanding of the concept?*

(b) Reflections on research design

As I have mentioned in the preceding subsections, my original background is in mathematics and physics. Indeed, the focus was on abstract mathematics and theoretical physics so I have a highly abstract and theoretical background and of the two, I would probably associate myself more strongly with mathematics than with physics as that was where my interest primarily lay. I subsequently went on to study Computer Science at a postgraduate level, although this was within a mathematics department and my dissertation in public key cryptography had a strong mathematical flavour. Since graduating, I have worked as a computing professional. In the beginning I worked in the early days of computer networking, when the networking systems required expert knowledge and in depth understanding. As time passed, I became highly involved in computer security systems and ran experimental services concerned with early information sharing and collaborative computer supported networked working. Industry trends to 'off the shelf' networking products meant computer networking was no longer such a challenging or interesting service area to be involved in. My interest in how people use technology increased through the experimental services I had been involved in and perhaps simply through experience in life. I, therefore, moved into an applied research and development role within the University when the opportunity arose. This – my current role – is based around collaborating with academics and services departments from across the University to research, develop and support the innovative use of technology within the institution. I am, thus, involved in interdisciplinary applied research and development as part of my work.

As the discussion on interdisciplinary and disciplinary knowledge in subsection 3.1.2 above suggests, my disciplinary background influences how I perceive the world, how I conceptualise phenomena and how I analyse things. Given my background this means that I am highly influenced by what might be termed hard science thinking and approaches. However, I would argue that mathematics, given its highly abstract thinking and exploration of the properties of differing number systems depending on differing fundamental axiom sets means that I am open to the existence of differing world views and potentially radically different underlying assumption sets. This grounding in abstraction means that I think it is perfectly acceptable to position myself outside the various abstractions. In what might be termed hard science, this would equate to positioning oneself as a neutral observer; however I would argue that from a mathematics training point of view it means that one can position oneself as overviewing many different thought domains or views on a real-world phenomenon rather than adopting a particular position. This means that I do not adopt any of the particular conceptualisations of emergence that are described in Chapter 2, section 2.3. My original training introduced me to the concept of emergence through the complex systems approaches; however having learnt about the others I now place myself outside them. Within the social sciences this might be deemed to be impossible and that one must belong, although perhaps unwittingly, to one of the perspectives. However, I would argue, that too is a view arising from a particular way of thinking – i.e. a disciplinary perspective.

My basic underlying assumption is that there is an objective reality which we can understand to varying degrees. Our understanding is based on our training – discipline and philosophical/religious /cultural – and the ontology of the real-world. This means that understanding, while reflecting an underlying objectivity is subjective in nature, giving rise to multiple interpretations arising from different thought domains. Thus, as discussed in subsection 3.1.2 above and further in Chapter 4, I contend that emergence is a concept which arises from an objective real-world, albeit potentially fuzzy phenomenon. Further, the ontology of the real-world may mean that there are parts of it which we might never be able to understand or scientifically explain. This is because nonlinear dynamical interaction means that information pertinent to such an explanation is lost over time. For example, there is insufficient information regarding the singularity that gave rise to the Big Bang to ever be able to describe or explain why the Universe came into existence.

A second assumption which undoubtedly arises from my mathematics background is that we can abstract – i.e. conceptualise – about real-world phenomena and analyse the relationships between them. As discussed earlier in this section, I conceptualised this initially in terms of a set of differing conceptualisations. Exploring how we might connect these differing conceptualisations so that we can communicate and carry out analysis was conceived of in terms of how functions – i.e. reasoning – could be supported, which in my training equates to the structural features of a topological space. This indicates a third underlying assumption – that the real-world can be sufficiently reflected in abstract thinking and modelling to allow us to explore and draw plausible conclusions regarding the real-world. The assumption here is that it is useful, not that such abstraction reveals an ultimate understanding or truth.

My background and the underlying assumptions which it has led me to make therefore have shaped this research. In particular, someone from a social science background would have conceptualised the problem and the solution in a very different manner, embedding themselves in the research rather than abstracting themselves from it.

In summary, this section has explained the focus of the research. The next section describes the methods employed to realise these research objectives and answer the research questions.

3.2 The research method – pragmatic, interdisciplinary conceptual analysis

The overall method which is adopted is that of pragmatic, interdisciplinary conceptual analysis. Conceptual analysis aims to propose how we might profitably conceive of some particular concept or group of interrelated concepts. It achieves this by exposing underlying subconcepts and related, potentially external concepts, breaking them down in order to reconstruct them to offer a plausible and useful way of understanding the concept (Swartz 1997). Within the pragmatic, interdisciplinary context of this research, conceptual analysis, I contend, needs to expose not only the differing subconcepts and their relations within different perspectives on emergence, but also how these differing subconcepts are related across the differing perspectives.

As Figure 3-3 below illustrates, the method comprises of three stages: extensive literature review and synthesis, conceptual development and assessment of the developments. In stage 1, extant literature from multiple disciplines and philosophical stances is reviewed and analysed to identify the full extent of the problem domain, its dimensions and variables, points of conflict together with key classic examples of emergence that can be used to reconceptualise emergence. Stage 2 uses the findings of the extensive review and synthesis to develop three conceptual proposals regarding emergence. Together, these three proposals answer *SQ-E* and *SQ-RW*. The final stage is to assess the plausibility and potential usefulness of the conceptual proposals and the research itself. As stages 1 and 2 employ the pragmatic strategy of using examples and examining conflicts and focus on core and key characteristics, the assessment of the success of the research answers *SQ-P – how might the claimed key characteristics, real-world examples and contradictions surrounding emergence be used to improve understanding of the concept?*

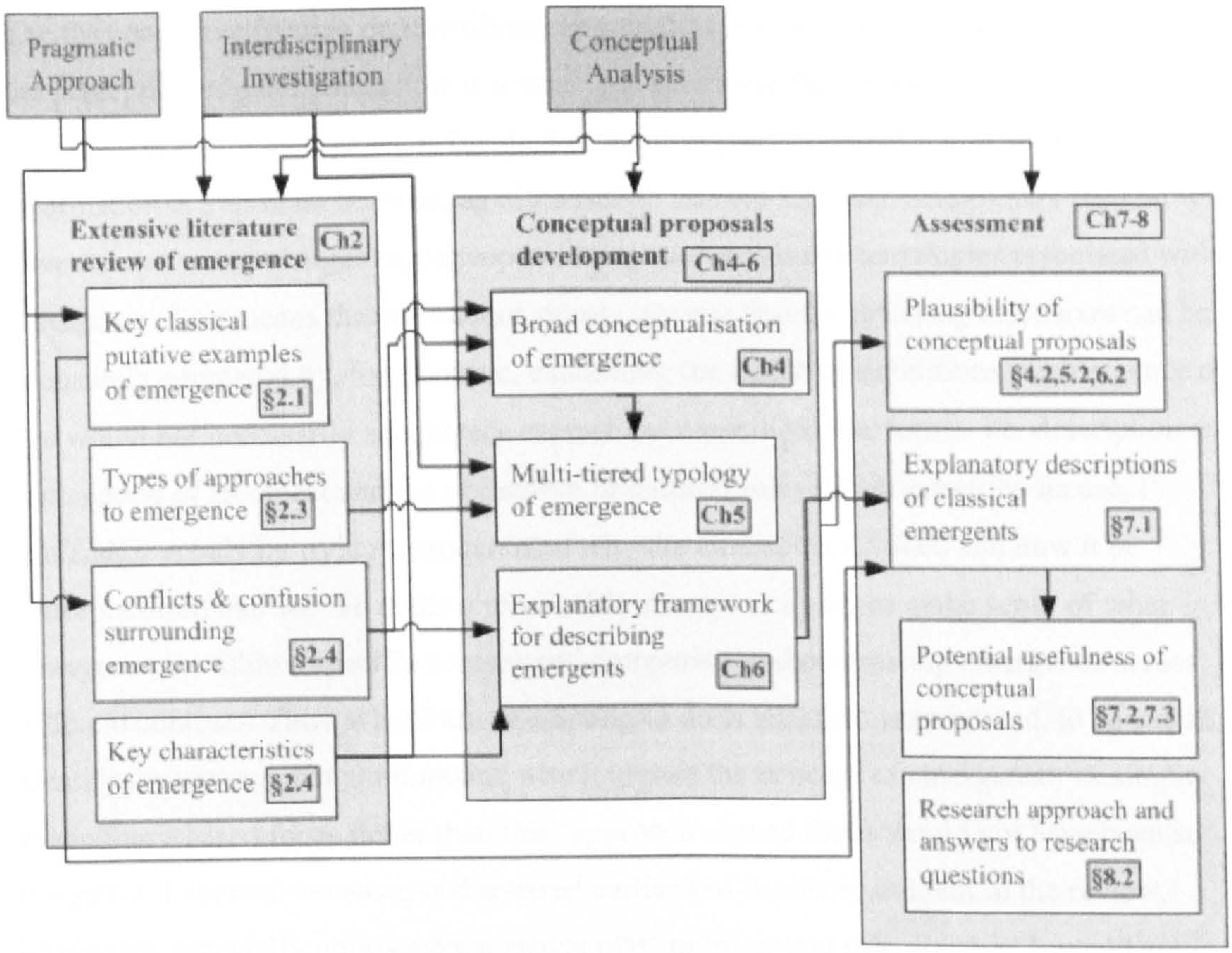

Figure 3-3: Overview of relationship of research methods and outputs

This operationalisation of the research differs from standard hard science research methods in two ways. Firstly, following my pragmatic approach, the operationalisation of the research stages evolved as the research progressed. Secondly, as discussed below, the literature review and analysis is far more extensive and forms a core part of the conceptual analysis undertaken within the research. This first stage, therefore, contains much of the conceptual work. How each of these three stages is operationalised is discussed in subsections 3.2.1 - 3.2.3 below.

3.2.1 Extensive literature review and synthesis

The extensive literature review and synthesis is a key 'instrument' in this research. It does not simply, as Patton (2002, p226) suggests, bring focus to the research through identifying what is already known and the cutting edge theoretical issues; rather it additionally embodies a key component of conceptual analysis and synthesis. Its objectives are two-fold: firstly, to explore the range and rationale of existing approaches to emergence; and secondly, to identify classic examples, key characteristics and conflicts that might be used to develop a broad conceptualisation of emergence. This latter objective follows directly from *SQ-P*. The rationale for setting the former objective is explained below.

The first objective focuses on identifying approaches to emergence. By an approach I mean the perception of emergence, how it is conceptualised and the rationale behind its usage – i.e. why the concept of emergence is invoked in the first place. I would argue that this information is important because, as discussed in section 3.1, each disciplinary context will have its own norms, language, conceptual frameworks and epistemologies associated with emergence. This means that we cannot simply assume that the differing discourses can be adequately compared by, for example, examining the differing definitions of emergence as this would not necessarily adequately capture the meaning of the term – i.e. description or explanation of an object and the normative or cultural rules which prescribe its use. I contend, it is only by trying to understand why the concept is invoked and how it is conceptualised that we can make a reasonable attempt at trying to make sense of what emergence is within a specific context and comparing and contrasting emergence across different contexts. Thus, what I am attempting to do is take into account and, to an extent, identify the various thought domains which invoke the concept of emergence. A simple disciplinary-based focus rather than this 'approach'-based focus would not have been so insightful, I contend because, as discussed earlier and is clearly evident in the review, ideologies, especially philosophical stance play an important role. Further, I would argue that by adopting this focus for the literature review, it allows a much more detailed picture of the 'emergence domain' to be built than in existing reviews of emergence.

The four key components of the literature review and synthesis stage – overall literature selection strategy; selection of classic examples of emergence; grouping of approaches to emergence; and analysis of emergence literature and synthesis – are discussed below.

Literature selection strategy

The two objectives of the literature review and analysis have three consequences for its operationalisation. Firstly, as the conceptual development is based on the review and analysis, the review needs to be largely completed before the conceptual development begins. Some further clarification of terminology or disciplinary context may however be required as the research progresses. Secondly, given the focus on developing a broad conceptualisation of emergence, the literature review must cover the differing disciplinary discourse on emergence. Thus, to ensure this cross-disciplinary domain coverage, literature is examined from multiple domains interested in emergence including philosophy, complex systems, biology, social sciences, business, economics physics and mathematics. Thirdly, the review must be extensive in nature. If it is not sufficiently extensive then there is a danger that the broad conceptualisation developed will not make a reasonable attempt at spanning the different thought domains regarding emergence. To ensure the review is extensive, a wide variety of differing keyword searches is used to identify sources from academic publications and relevant discussion forums. These searches are based on general and discipline specific terms and are extended as new key concepts and terms are identified. Clearly, there will always be a risk that some literature might be missed. However, the pragmatic approach adopted allows for revision as required.

Classic examples of emergence

In order to compare and contrast the literature from differing disciplines and perspectives key classic examples of emergence are considered. These examples are purposefully selected from the extant literature[48] on the subject to illustrate the different characteristics which are often associated with emergence as well as the wide range of interpretations of the concept of emergence itself. In particular, examples which illustrate unresolved conflicts between disciplinary perspectives/thought domains or which are central to specific disciplinary interest in emergence are selected. So, for example, life is selected as representative of interest within biology, mind is representative of philosophical interest and social capital is chosen to represent business/social science interest. While a wide range of examples are used within the actual review process, the discussion of the review presented in Chapter 2, focuses on 10 representative classic examples – mind, life, structure of the Universe, social capital, thermodynamics, the smell of ammonia, patterns and stripes, the function of a machine, the World Wide Web and the property of being a circle. These chosen examples are not necessarily considered emergent within all the varying conceptualisations. The rationale for the choice of these particular examples is summarised in Table 3-1 below.

Example	**Typical of discipline perspective**	**Selection rationale**
Mind	Philosophy	The relationship between the mind and physical brain illustrates the potential irreducibility associated with emergence
Life	Biology	Captures novel ontological phenomenon which gives rise to a new 'level'

[48] The use of examples is a common theme within the philosophical discourse on emergence.

Example	**Typical of discipline perspective**	**Selection rationale**
Structure of the universe	Physics	Captures novel ontological phenomena which radically change rules and environment
Social capital	Social Science/ Business	Illustrates how novel networked phenomena can arise through of non-linear social interaction
Thermodynamic properties	Physics	Illustrates how macro level phenomena can be the result of current theory, language or perception
Smell of ammonia	Chemistry	Illustrates how macro-level properties may lie in the relation between phenomena
Patterns and stripes	Chemistry; biology; Computer and Information Sciences	Illustrates how self-organisation of non-linear interactions can give rise to new macro-level patterns
World Wide Web	Computer and Information Sciences	Illustrates how self-organisation of non-linear interactions can give rise to unpredictable novel macro-level phenomena; Illustrates how layers of emergence make it difficult to definitively assign causal influence
Function of a machine	Engineering	Illustrates how macro-level properties may lie in the relation between phenomena ; Illustrates that additional unpredicted emergence can arise
Property of being a circle	Mathematics; Philosophy	Illustrates how choice of reference levels and terminology affects perception as emergent

Table 3-1: Summary of rationale for examples selection

Clearly many different examples could have been used. For example, the emergence of business strategy could have been selected in place of social capital for a business-related example. The latter is chosen as I have more in-depth knowledge regarding social capital and so I am able to bring my existing knowledge to bear in the analysis rather than having to undertake further intensive research on a new topic. It could be argued that some of the classic examples from the literature are 'bad' examples of emergence as they are not universally agreed, representing only a limited perspective. Indeed, at the outset of this research, I personally would not have considered the property of being a circle emergent. However, I would contend that given my focus on understanding differing extant perceptions and conceptualisations of emergence, it is important to use existing examples from the extant literature on emergence, as these capture the differing perceptions. To introduce radically new examples would involve considerable speculation regarding how different disciplines might interpret them.

Two additional examples – two rowers in a boat and diffraction patterns – are used to illustrate phenomena that, I claim, are not intuitively emergent, although they have some similar properties to the ten putative emergents. These examples arise from discussions with colleagues from different disciplines regarding what are not examples of emergence. The 10 examples and 2 counter examples are presented in Chapter 2, section 2.2 and are returned to throughout the thesis to aid analysis of emergence and to help assess the plausibility of the conceptual developments.

Review and grouping of approaches

The review of existing approaches to emergence is presented in Chapter 2, section 2.3.

In order to start to 'make sense' of the variety of approaches to emergence it is useful to group the differing approaches to emergence in some meaningful way. By meaningful I mean that the grouping should help move the research forward to the ultimate goal of developing a broad conceptualisation of emergence. A variety of grouping strategies could be adopted. For example, the approaches could be grouped, as in previous attempts by others, by conceptualisation, philosophical stance or key characteristics. As the literature review is concerned with understanding the different approaches to emergence, I argue that a sensible way initially to group the differing approaches is by the rationale for invoking the concept – that is by the type of general feature or problem that the concept is invoked to address. This is in line with my problem-driven research focus – i.e. the grouping relates to the problems that the concept of emergence is invoked to capture. Further, I deliberately do not categorise by discipline at this stage because as the analysis of Chapter 2, subsection 2.4.1 illustrates, I am interested in analysing whether these different types of approaches are influenced by the disciplines.

This grouping was undertaken by identifying meta-level rationales for the differing conceptualisations and grouping them accordingly. For example, the literature illustrates that conceptualisations of emergence developed by the early British emergentists were developed in a response to attempts at analysing whether apparently novel phenomena such as life or the mind are ontologically distinct from their constituent parts. The grouping was achieved by identifying potential rationales for invoking the concepts from the literature as it is read.

Post-its for each rationale, labelled with an appropriate summary name from the literature, were then created. These were then analysed by considering various groupings to see if overarching or meta-level groups could be identified. If so, a new meta-level label (rationale) was identified and the sub-labels appropriately assigned. This iterative process was repeated until no new meta-level rationales were identified. From this analysis three broad meta-level approaches to emergence emerged – emergence as ontological novelty; emergence as epistemological novelty and emergence as the product of a complex system. Importantly these terms are taken from the literature and are not 'adjusted' to be of similar conceptual types, because they arise for very different reasons. The terms and the grouping are, thus, grounded in the literature rather than a predefined conceptual framework.

These three broad approaches to emergence are simply useful ways of thinking about approaches to emergence, grounded in the rationales for employing the concept. Individual conceptualisations may be much more complex, being influenced by multiple rationales. So the grouping is not expected to partition uniquely the broad emergence domain into three groups. However, as Chapter 2 illustrates, this synthesis provides a useful framework for discussing approaches to emergence and identifying their key characteristics. The usefulness derives from the fact that it includes information relating to why approaches arise and it is deliberately different from existing methods of categorising conceptualisations of emergence such as Stephan (1992) and Clayton (2006a) who group conceptualisations of emergence from a historical perspective and Silberstein (2002) who considers ontological and epistemological views of emergence. Thus, this novel grouping exposes key characteristics and differing perspectives, affording novel comparisons.

Analysis of the literature and synthesis

The final component of the literature review and analysis stage is to try to extract what can reasonably be synthesised about emergence from the review process. The following four questions are posed to help unpick why it has been so difficult to develop a shared understanding or generally accepted definition of what emergence is.

The first question – *why are there such different approaches to emergence* – draws out the major factors which lead to the multiple approaches. Understanding why these different approaches arise is, I contend, important if the broad conceptualisation to be developed is to be applicable in the varying disciplines and communities interested in emergence. Further, exposing the rationale for approaches will help ensure that I do not make incorrect assumptions based on my own disciplinary background.

The second question – *why is confusion regarding emergence persistent* – follows from the overall pragmatic approach. In particular it is designed to help identify conflicts that need to be resolved if a broad conceptualisation is to be developed. These conflicts may reveal language or perceptual differences or simply misconceptualisations. The former identifies where translations between different disciplinary understandings will be necessary and the latter where general conceptual understanding needs to be further developed.

The third question – *what may be concluded about emergence* – explores what might be synthesised regarding emergence in terms of core characteristics; non-core but key characteristics (relating to instantiation of emergents; generators of emergence; behaviour of emergents) and types of emergence. The core and key characteristics identify the necessary components and variables of the broad conceptual domain relating to emergence and the types of emergence illustrate how emergence has been categorised in the literature to date.

The final question – *why is understanding of real-world emergents difficult* –helps identify how understanding of real-world emergents might be improved (*SQ-RW*). The implications of the ontology of emergents and how we observe and analyse them are considered.

This synthesis then forms the basis for the conceptual developments of the thesis, the operationalisation of which is discussed in the next subsection.

3.2.2 Conceptual development

The objective of the second stage of the research is development of the three conceptual proposals – the broad conceptualisation of emergence (S*O1*), its elaboration (S*O2*) and the tool for generating an explanatory description of real-world emergents (S*O3*). This is achieved through the standard conceptual analysis techniques of reconstituting the subconcepts and relations pertaining to emergence described in the introduction to this section. The subconcepts and their relations were identified in the literature review and synthesis stage. The key focus is to ensure that, as discussed in subsection 3.1.3, interdisciplinary conceptual tools are developed which provide a framework for increasing transdisciplinary and disciplinary understanding of emergence and emergents. How each of these is achieved is discussed below.

(a) Development of the broad conceptualisation of emergence

The objective of developing the broad conceptualisation of emergence is to develop a transdisciplinary conceptualisation that integrates and bounds the broad conceptualisation.

Further, as discussed in subsection 3.1.3(b), it is important that the conceptual developments of the epistemological bridge make 'epistemological sense'. This broad conceptualisation is specified in three steps.

The first step is to state what broad means in epistemological terms. My claim, here, is that emergence is a fuzzy concept. Fuzzy concepts are a well-recognised phenomenon and my claim that emergence is fuzzy derives from the observation that existing definitions of emergence seem to overlap in some unclear way. This is exactly what Wittgenstein (1954) sought to capture in his proposal of family resemblance concepts – now more commonly termed fuzzy concepts. This is discussed in detail in Chapter 4, subsection 4.2.1. By conceptualising emergence as fuzzy this effectively provides a way of integrating the various extant conceptualisations within a sound epistemological framework.

The second step is to specify what characterises a phenomenon as emergent in the broadest sense – i.e. what are the necessary conditions for a phenomenon to be considered emergent within the broad conceptualisation. This is achieved through stipulating the core characteristics of emergence which were identified through the analysis of the literature review of section 2.4.3. These core characteristics are the common characteristics that can be synthesised from consideration of the range of conceptualisation of emergence. As discussed in subsection 3.1.3(b), this effectively bounds the broad conceptual domain associated with emergence.

The third step is to specify the key dimensions of the broad conceptual space pertaining to emergence. The objective of specifying a specific set of dimensions is to identify the types of subconcepts and relations that require to be considered to ensure coverage of the conceptual domain. Different interpretations of the dimensions may be equally valid provided they afford the same coverage. What we are concerned with is how to integrate (and differentiate) understanding from different disciplines and philosophical stances, therefore the dimensions– ontological, epistemological and complexity – are extracted from the differing types of information relating to emergence, identified in the literature review.

Given the conceptual analysis strategy of not defining things too early discussed in subsection 3.1.3(b), the following 'caveats' are added:

- The micro-level system components may or may not be interconnected;
- 'not manifest' may be a result of the ontological status of the property or epistemological considerations such as the scope or resolution of the observation of the emergent.

These caveats are introduced in order to remain as open as possible. For example, if there was an insistence that micro-level components be interconnected, it would imply a strong[49] complexity perspective which would exclude many interpretations of thermodynamics. Similarly, the second caveat ensures that the definition accommodates both ontological and epistemological views on emergence.

The resulting broad conceptualisation is presented in Chapter 4, section 4.1.

(b) Development of the elaboration of the broad conceptualisation of emergence

The objective of the elaboration of the broad conceptualisation is that it (i) spans and differentiates the broad emergence domain and (ii) supports analytical discussion within both interdisciplinary and disciplinary contexts. This is achieved, in Chapter 5, through development of a multi-tiered typology of approaches to emergence. This choice of a typological approach is a result of the realisation that, in grouping and subgrouping the approaches and conceptualisation to emergence found in the literature in order to review their rationales and characteristics, I have effectively developed a typology of approaches to emergence. Further, within each of the three broad approaches – effectively the top tier of the typology – I have identified a range of sub-approaches or conceptualisation of emergence. As I explain below, this form of typology satisfies the requirements for the elaboration of the broad conceptualisation.

(i) Spans and differentiates

Typologies are commonly employed to classify phenomena – real-world or conceptual – to partition the domain of interest into a form suitable for further analysis. Thus, provided a suitable categorisation scheme is used, a typology is an appropriate tool to span and differentiate the broad emergence domain. There have been several attempts at developing typologies of emergence – (Stephan 1992, Bedau 1997, Jones 2002, Silberstein 2002, Bar-Yam 2004, Fromm 2005, Ellis 2006). However, as I discuss in Chapter 5, subsection 5.2.2, these all fail to either span or adequately differentiate the broad emergence domain.

(ii) Supports analytical discussion within interdisciplinary and disciplinary contexts

Typologies facilitate communication and comparison by grouping a domain into a number of 'types'. These types can then be used to provide general descriptions of the characteristics

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[49] By strong complexity perspective, I mean that the components must be connected non-linearly.

that phenomena of a particular type will have. This explicit description of the types of the typology enables the different participants to share the meaning of these types – an important capability in interdisciplinary discourse (Wear 1999). For example, Bedau's (1997) typology which distinguishes emergents into nominal, weak and strong types is often used to share what is meant by weak and strong emergents, thus bringing clarity to communications. However, as discussed in Chapter 2, subsection 2.3.1, Bedau's typology demands a particular philosophical view – that emergence is ontological in nature – and so will fail to bring out the advantages to be gained from considering the full range of conceptualisations of emergence.

The identification of types also allows discussions to be generalised to groups of phenomena with similar properties. While the extent of what might be reasonably said depends on how the typology has been constructed, even the simplest typology may be used to explore differences between types. Bedau's typology, while simple – based on the degree of irreducibility, has been extremely useful in this respect. As Bedau (1997) illustrates, it also allows a degree of supposition as to how nominal and weak emergents arise. Thus, it can be said to help explain at least this particular conceptualisation of emergence.

A typology can be used to group or match objects in two broad ways. In *strict matching* an object is matched with a specific type if, and only if, the object matches all the requirements – i.e. characteristics – of the specified type, while in *loose matching* an object is matched if it shares at least one characteristic of the type. Based on the type of matching being undertaken, typologies support more extensive extrapolation regarding phenomena in two ways. Firstly, they can be used to support prediction and extrapolation based on characteristics. For example, if a phenomenon has a certain characteristic then it (i) must belong to a specific type and (ii) as a result it will also possess the other characteristics shared by the type but not characteristics exclusive to a different type. This ability depends on the typology being based on strict categorisation criteria which uniquely allocate a phenomenon to exclusive sets – what Doty and Glick (1994) term 'classification systems' or taxonomies. For example, Jones (2002) uses his typology, which exclusively classifies types by different 'organising relations', to infer that emergence which occurs within a system of 'mutualistic feedback' will lead to cooperative behaviour and evolution, while systems with only simple feedforward relations will not. For such deductions not to be mere tautology, the types of these 'classification system' typologies should have distinct meaning apart from their classification criteria. That is, as Kluge (2000, §2) argues, there should be strong internal homogeneity within the constructed types while strong external heterogeneity at the top level of the typology. Strong internal homogeneity implies that there are meaningful relationships (Weber 1972/1921, cited in Kluge 2000) between the instances of a type – that the instances are not just of the same type for some random or tautological reason. Kluge, in her attempt to provide a general conceptualisation of types within a typology, is thus loosening the need for a strict categorisation system. The actual types of types may include what she terms ideal types, empirical types, structure types, prototypes. As shall be discussed below, not all of these types uniquely partition a typology. Importantly, Kluge strongly advocates that the construction of typologies is empirically grounded. This leads to a second type of extrapolation. As Kluge argues, sub-analysis of the different types within each broad type may expose meaningful relations between the characteristics.

Secondly, typologies may be used as a tool to predict where new examples of a given type might be found. This is possible where: (i) the categorisation is based on particular generating conditions as in the case of Jones; (ii) there is strong homogeneity of types and a correlation to where instances might be found; or (iii) it is an 'idealised type' typology. 'Idealised type' typologies consist of "conceptually derived interrelated sets of ideal types" (Doty and Glick 1994, para 8)[50] and are different from 'classification system' typologies as they do not partition the domain of interest into exclusive sets. Rather, according to Doty and Glick, they are designed to highlight both the interesting (extreme) cases and the norms which might theoretically arise by considering the range of variables within a given subject domain. For example, they contend each idealised type should be represented by a complex and unique combination of the domain 'dimensions'. Thus, within organisational science – Doty and Glick's domain of interest – idealised types of organisations might be built as Mintzberg (1979) does through consideration of age, size, environmental uncertainty, formalisation, specialisation and centralisation. Consideration of what they term the 'domain dimensions' and their variables will enable prediction of where new examples of the type might be found. For example, organisations of a particular size and age within a specific environmental uncertainty will be of the corresponding type. Thus, the conceptual basis of their construction enables 'idealised type' typologies to be used to predict where new examples might be found through consideration of the dimensions and variables from which

[50] Doty and Glick (1994) in fact exclude categorisation systems and taxonomies from typologies, retaining the term typology purely for what is referred to here as an 'idealised type' typology.

the idealised types are built. Additionally, exploration of why different variables might give rise to phenomena with certain characteristics can be supported.

The preceding paragraphs argue that typologies can usefully facilitate communication, help clarify meaning and support comparison. They can also support more analytical type activities such as extrapolation and prediction depending on their epistemological structure – categorisation system or idealised type – and how their types have been developed. Returning to the discussion of the 'conceptualisation' of the broad conceptualisation, in subsection 3.1.3(b) it is identified that the elaboration should capture the differing thought domains pertaining to emergence. This is exactly what the groupings of approaches to emergence and their subgroupings which are presented in the literature review of Chapter 2, section 2.3 do. As I will illustrate in Chapter 5 and Chapter 7, this typology can be used to support loose and strict matching of conceptualisation of emergents and of emergents. Further, the typology, I claim, is an idealised type typology as its component types are based on differing conceptualisations of emergence, each of which emphasises a differing set of key domain variables – i.e. the key characteristics. Thus, such a typology should have the advantage that it facilitates the more advanced analytical activities discussed in subsection (ii) above. The multi-tiered typology which addresses SO2 is then created by assigning each of the three broad approaches to emergence, identified in subsections 2.3.1-2.3.3 respectively, to the three top-level types – *//Ontological_novelty*, *//Epistemological_novelty* and *//Product_of_complex_system*. The sub-groupings for each of these approaches, which are identified in subsections 2.3.1-2.3.3, are then assigned to be the next level of types within the multi-tiered typology. This is repeated until no more subtypes exist – i.e. until 'leaf' subtypes are identified. For each 'leaf' subtype, the key characteristics that are associated with this subtype – i.e. with this conceptualisation – are identified. These are the domain variables associated with the idealised sub-type. This is represented visually – see Figure 5-1, p156 – by combining the figures – Figure 2-4, p39, Figure 2-5, p47 & Figure 2-6, p58 – which summarise three different broad approaches, their associated conceptualisations and their key characteristics.

In summary, the multi-tiered typology presented in Chapter 5 is chosen for purely pragmatic reasons – it emerged from the literature review process and satisfied the criteria for an elaboration of the broad conceptualisation of emergence. Following the research's pragmatic, fit for purpose approach, other choices for the elaboration were not considered.

(c) Development of a tool for generating explanatory descriptions of real-world emergents

The objective of the tool for generating an explanatory description of real-world emergents is that it can be used within the general broad emergence domain to: (i) establish whether a real-world phenomenon is emergent; (ii) clarify exactly what the 'is emergent' relation is; and (iii) describe the full range of core and key characteristics relating to the instantiation, generation and behaviour of the emergent under consideration. The question then is – what kind of conceptual tool can generate such explanatory descriptions of real-world emergents? Two general methods present themselves. The descriptions could be developed through a modelling approach – conceptual or computer – which involves prediction of characteristics from idealised descriptions rather than real-world grounded descriptions. Alternatively, the descriptions could be generated by examining the phenomena themselves. I contend that a modelling approach would be inappropriate as it would involve either adopting a preferential conceptualisation as the basis for the model or developing a brand new 'super model of emergence' which integrates the existing conceptual models. The former would be counter to the whole broad conceptualisation approach – see subsection 3.1.2(c) – and in the latter case, as the discussion of subsection 3.1.2(b) argues, given the current state of understanding the super model would be too abstract to be of real value in producing meaningful/useful descriptions. The choice then is to develop the descriptions from the real-world phenomena themselves. This is achieved through an explanatory framework, present in Chapter 6, section 6.1, which guides the researcher/practitioner through the key details which need to be examined in order to generate a description of a real-world phenomenon that will (i) enable it to be established whether the real-world phenomenon is emergent; (ii) clarify exactly what the 'is emergent' relation is; and (iii) describe the full range of core and key characteristics relating to the instantiation, generation and behaviour of the emergent under consideration. How the framework is developed is described below.

Returning to Patton's (2002) recommendation to base the design on the problem to be addressed, the first step in designing the framework is to return to the general problems identified in Chapter 2, subsection 2.4.4 regarding why emergents are difficult to understand. As discussed in that section, the problem is concerned with the complexity of such phenomena's causal structure combined with epistemological factors relating to how we observe and analyse emergence. This is exactly the types of phenomena that complex systems approaches are interested in. The framework is therefore designed to explore the complex causal system – termed the 'emergence system' – which gives rise to the phenomenon under consideration and its epistemological influences. Concentrating on the emergence system does not, I contend, mean that I have adopted a preferential view of emergence as being the product of a complex system, because it is still possible to examine synchronic emergence within the overall diachronic framework that complex systems approaches adopts. Two other implications for the framework design arise from the inclusion of examination of epistemological influences. Firstly, as the discussed in Chapter 2, subsection 2.4.3, scope and resolution affect how we observe and describe a phenomenon. Thus the descriptions will need to accommodate this. This is achieved by including description of how different scopes and resolutions affect how we perceive a phenomenon and so the differing views will be made explicit rather than deciding on a particular epistemological view. Secondly, this degree of complexity and lack of objectivity suggests that the framework needs to be pragmatic and use iterations to refine the descriptions until satisfactory. 'Satisfactory' is measured against compatibility with real-world observation, fitness for purpose– i.e. exactly what the description will be used for – and current levels of understanding. Based on this emergence systems approach which involves iteration and multiple epistemological views, the 4-stage framework is developed as follows.

Core to complex systems approaches is that the phenomenon under investigation cannot be considered in isolation as it arises within a potentially open nonlinear causal network (Chu et al. 2003). The starting point, therefore, is to establish what the emergent phenomenon under consideration is – i.e. exactly what the relevant macro-level phenomenon and its micro-level components are – and to identify the range of causal influence that either might affect or be affected by the phenomenon. Drawing on the key reasons, identified in Chapter 2, section 2.4, which make understanding emergence and emergents difficult, the framework achieves this by asking the researcher/practitioner to consider: the range of possible macro-micro relations that could describe the emergent; how these are related both diachronically and synchronically; what are the key organisational features that give rise to the emergence – identified in subsection 2.4.4(a); and how epistemological factors could affect perception – identified in subsection 2.4.4(b). The latter is particularly important as the framework is trying to identify the characteristics independent of perspective. This forms stage 1 of the framework and is repeated until a satisfactory description of the emergent and its complex causal emergence system is developed.

The next three stages (2-4) of the explanatory framework address the description of the full range of key characteristics associated with emergence in its broadest form. The development of stage 2 is described next.

In order to help describe the key characteristics associated with the instantiation of the emergent, the framework guides the researcher/practitioner to consider each of the three key characteristics associated with the instantiation of an emergent – surprise, predictability from its constituent parts and the degree of (ir)reducibility of its explanation to its component parts – which were identified from the analysis of the literature in Chapter 2, subsection 2.4.3(b) as being most useful in understanding conceptualisation of emergence Non-deducibility is not included as a separate characteristic as it is dealt with by considering the implications of differing resolutions on the degree of irreducibility. As one of the key issues identified in subsection 2.4.4 is the variation in interpretations of these characteristics, the framework provides a list of the different forms that these characteristics might take. For example, the key characteristic of *'Reducibility of explanation'* can take the form of *sum, (complex) product* and *irreducibility*. Again, these differing forms are taken from the differing interpretations of the key characteristics discussed in subsection 2.4.3(b) which were extracted from the extant literature itself. The differing key characteristics and their forms are presented in table form, with examples to clarify their meaning – see Table 6-1, p178. The research/practitioner works their way through the table to develop a description of the key characteristics associated with the instantiation of the phenomenon under consideration. This forms stage 2 of the explanatory framework and is presented in detail in Chapter 6, subsection 6.1.2.

Stages 3 and 4 of the framework address development of descriptions of the key characteristics associated with the generation and behaviour of the emergent respectively. These stages take the same form as described above for the instantiation characteristics and are based on key generation and behaviour characteristics identified in subsections 2.4.3(c) and 2.4.3(d) respectively. Stages 3 and 4 of the explanatory framework are presented in detail in Chapter 6, subsection 6.1.3 and 6.1.4 respectively.

Having presented the methods used to develop the three conceptual proposals – the broad conceptualisation of emergence, its elaboration through a multi-tiered typology and the explanatory framework for describing real-world emergents – the next subsection considers how their plausibility and potential usefulness and the research in general is assessed.

3.2.3 Assessment of the research

The assessment strategy adopted in this research focuses on assessing the profitability – i.e. the plausibility and potential usefulness – and limitations of the conceptual proposals and the research itself. Assessing plausibility – that a conceptual proposal has the desired characteristics and does not violate common sense or observations – is the standard assessment method used in conceptual analysis, hence its inclusion in the assessment strategy. Assessment of the potential usefulness is also included as I am concerned with developing tools that will help develop insights into the difficult problem of what emergence is and how understanding of real-world emergents might be increased. As Figure 3-3, p112 illustrates, the assessment is carried out in four stages, which are dictated by the dependencies and independencies of the conceptual developments and how the explanatory framework can be used in the assessment process. In particular, as the explanatory framework does not directly depend on either the broad conceptualisation or its elaboration, it can be used to develop explanatory descriptions of real-world emergents which in turn can be used to assess the plausibility and potential usefulness of the first two conceptual proposals. The assessment criteria are first discussed below, followed by a description of the four stage assessment process.

Assessment criteria

The criteria used to assess the three conceptual proposals and the success of the research are discussed in turn below.

(a) Assessment of the broad conceptualisation of emergence

As discussed in subsection 3.1.4, the objective of developing the broad conceptualisation of emergence is to develop a transdisciplinary conceptualisation that integrates and bounds the broad conceptualisation. If it is to achieve this in a plausible and potentially useful manner, I contend, it should satisfy the following three criteria. Firstly, as discussed in subsection 3.1.3(b), the broad conceptualisation should be epistemologically sound. Without this, the incorporation of the differing conceptualisations into one broad conceptualisation may not make sense. As discussed in 3.2.2(a), the claim here is that emergence is epistemologically a fuzzy concept. Secondly, while the aim is to make the conceptualisation sufficiently broad to include the various existing conceptualisations, it should still capture the normative usage of the concept. Swartz (1997) argues that this is an important aspect of any profitable conceptualisation because otherwise the concept will have become so stretched that it no longer captures the essence of what it was originally about. Finally, the broad conceptualisation should, as a minimum, identify the key dimensions of the conceptual domain surrounding emergence. The aim of specifying a specific set of dimensions is to identify the types of subconcepts and relations that will require to be considered to ensure coverage of the conceptual domain. Different interpretations of the dimensions may be equally valid provided they afford the same coverage. However, what we are concerned with is how to integrate understanding from different thought domains. Therefore, I argue that a set of dimensions which, not only provides coverage but emphasises the different motivations for us to develop the concept in the first place will be more profitable. Further, the dimensions should be sufficiently distinct to contribute differing insight although a degree of overlap will aid validity of conclusions. The emphasis is, thus, on profitable coverage of the conceptual domain and there is no requirement for the dimensions to be orthogonal or unique.

These criteria relating to the plausibility of the broad conceptualisation of emergence and how and where these are assessed are summarised in Table 3-2 below.

Criteria	**Type of assessment**	**Assessment activity**	**Section**
Is epistemologically sound – i.e. is a valid fuzzy concept	Plausibility	(a) Analysis of conceptual structure and claim to intrinsic fuzziness through consideration of extant literature; (b) Cross-comparison of claimed key characteristics of descriptions of real-world emergents to illustrate no sufficient characteristics.	4.2.1 7.3.1
Captures broad but normative usage of the concept	Plausibility	Illustrate fit of classic examples within, but exclusion of the two counter examples from, the broad conceptualisation.	4.2.1
Identifies (useful) dimensions of the concept	Plausibility	(a) Illustrate that the dimensions: (1) provide coverage of the broad emergence domain while emphasising the different motivations for the concept; (2) are sufficiently distinct to contribute differing insight; and (3) provide a degree of overlap to aid validity of conclusions;	4.2.1 7.3.1

Criteria	Type of assessment	Assessment activity	Section
		(b) Cross-analysis of dimensions from explanatory descriptions.	

Table 3-2: Summary of the criteria and assessment activity for the broad conceptualisation of emergence

(b) Assessment of the multi-tiered typology of emergence

As discussed in subsection 3.1.4, the objective of the elaboration of the broad conceptualisation, which is realised through the multi-tiered typology, is that it (i) spans and differentiates the broad emergence domain and (ii) supports analytical discussion within both interdisciplinary and disciplinary contexts. As discussed in section 3.2.2(b), typologies can usefully facilitate communication, help clarify meaning and support comparison. Further, they can also support more analytical type activities such as extrapolation and prediction depending on their epistemological structure – categorisation system or idealised type – and how their types have been developed. The plausibility of the multi-tiered typology as a tool for supporting analytical discussion can, I argue, be assessed using the three criteria discussed below. Its potential usefulness will depend on its actual ability to support the different analytical activities.

Firstly, the proposed typology must adequately span the domain under investigation. Given the pragmatic ethos of the research, adequately span means covering not only the various conceptualisations of emergence but also ensuring that areas of conflict are highlighted – i.e. both the full range of emergence and the 'interesting (extreme) cases' should be spanned. Secondly, the typology should have a strong conceptual base as opposed to an empirical base. This is primarily due to the fact that a purely empirical basis for a typology of emergence will be problematic given the lack of agreement regarding what emergence actually is. Such a requirement is clearly compatible with idealised type typologies and, therefore, part of a sound epistemology. As the discussion of the focus of this research in subsection 3.1.2(c) and 3.1.3(b) argues that we need to make explicit existing conceptualisations within interdisciplinary discourse, I contend, an appropriate conceptual basis within the context of this interdisciplinary research is the existing conceptualisations and their characteristics. However, together these existing conceptualisations are not globally consistent.

This leads to the third broad criteria. Like this research, the typology should concentrate on being fit for purpose as opposed to implementing a unified, unique categorisation framework for emergence. There seems little choice but to adopt such an approach as understanding of emergence has not reached a unified, crisp conceptual understanding[51] let alone theory and so, I would argue, any strict categorisation approach may not sufficiently highlight the interesting cases from which we might profitably learn. By adopting a fit for purpose approach, a typology could be built which is locally consistent within types or subtypes but not globally consistent. I would argue that such a typology can still be used to support analytical analysis provided the typology makes explicit the basis for types and subtypes and the relationship between them. This does not imply that there must be a close conceptual relationship between distant subtypes. Rather, where a relationship exists it should be made explicit. This will then still enable analytical discussion and comparison across types on why they are different at a meta-conceptual level. Thus, the typology should be locally consistent and globally coherent.

These criteria relating to the plausibility and potential usefulness of the multi-tiered typology of emergence and how and where these are assessed are summarised in Table 3-3 below.

Criteria	**Type of assessment**	**Assessment activity**	**Section**
Adequately spans and differentiates the domain	Plausibility	Analysis of domain coverage and differentiation of interesting cases;	5.2.1
Locally consistent and globally coherent	Plausibility	Analysis of the conceptual structure – i.e. the relationship between types and subtypes within the typology	5.2.1
Conceptually founded	Plausibility	Analysis of the selection of types and subtypes	5.2.1
Facilitates conceptual analysis across and within thought domains	Potential usefulness	Illustration of capability to: (a) Loosely match explanatory descriptions of real-world emergents; (b) Facilitate comparison and generalisation relating to the descriptions of the real-world emergents;	7.3.2

[51] Note: there is no claim that this can be reached.

Criteria	Type of assessment	Assessment activity	Section
		(c) Facilitate prediction and extrapolation of characteristics	

Table 3-3: Summary of the criteria and assessment activity for the multi-tiered typology of emergence

(c) Assessment of explanatory framework for describing real-world emergents

As discussed in subsection 3.1.4, the objective of the tool for generating an explanatory description of real-world emergents is that it can be used within the general broad emergence domain to: (i) establish whether a real-world phenomenon is emergent; (ii) clarify exactly what the 'is emergent' relation is; and (iii) describe the full range of core and key characteristics relating to the instantiation, generation and behaviour of the emergent under consideration. Subobjectives (i) and (ii) capture the fact that the explanatory framework is intended to facilitate practical improvements in understanding real-world emergents and hence assessment of its ability to support these tasks is a good measure of its potential usefulness. However, if the explanatory framework is to achieve this in a plausible and potentially useful manner, I contend, it should also satisfy the following criteria.

Firstly, I contend, the description should be 'neutral' but conceptually-relevant. Conceptually-relevant is required if the description is to be appropriate for the task at hand, especially if we are to use the description in combination with the multi-tiered typology to further explore both emergents and emergence in general. However, as discussed in Chapter 2, the various conceptualisations bring with them conceptual baggage and, as argued in subsection 3.1.2(c), none of the conceptualisations should be considered preferential. Thus, the description needs to be neutral to these various conceptualisations of emergence if we are to avoid existing problems and develop descriptions/explanations which are meaningful across and within different thought domains and their resultant conceptualisations. This will also have the benefit that such descriptions can be used within differing subtrees of the multi-tiered typology, thus increasing the extent of the conceptual analysis that may be undertaken. Secondly, and relatedly, the plausibility of the framework clearly depends on its ability to facilitate description of the instantiation, causation and behaviour of an emergent. Thirdly, the description should include how different epistemological factors might affect the description. This is critical if the description is to be valid beyond one individual's perception of the phenomenon. Further, I would contend, it would be difficult to argue for improved understanding of the emergent if this were not included because critical areas of disagreement would still exist. Also, the description should capture the emergent and its causal environment. As discussed in Chapter 2, subsection 2.4.4, failure to adequately consider what exactly the emergent under investigation is, and the full extent and implications of its causal structure, have been significant contributing factors to the confusion and disagreement surrounding emergence. Finally, the description should make explicit what is meant by the key characteristics it identifies. Without this, it is open to ambiguity and may not be coherent across disciplines and individual perceptions.

These criteria relating to the plausibility of the explanatory framework and how and where these are assessed are summarised in Table 3-4 below.

Criteria	**Type of assessment**	**Assessment activity**	**Section**
Develops 'neutral' but conceptually-relevant description of the emergent	Plausibility	(a) Analysis of independence of philosophical stance and specific disciplinary perspectives, language and norms; (b) Analysis of coverage of key characteristics pertaining to the differing conceptualisations of emergence.	6.2.1
Describes the instantiation, causation and behaviour of the emergent	Plausibility	Illustrate coverage of key characteristics pertaining to instantiation, causation and behaviour of emergents extracted from the literature review.	6.2.1
Pays particular attention to: causal environment; epistemological influences; meaning of key characteristics	Plausibility	Illustrate how these are covered by the explanatory framework.	6.2.1
Be of practical use	Potential usefulness	Generation of descriptions of real-world emergents and discussion of limitations.	7.1, 7.2, 7.3
Improve clarity of explanation of real-world emergents	Potential usefulness	Analysis of descriptions of example real-world emergents.	7.1, 7.2
Aid analysis of assessment of whether a real-world phenomenon is emergent	Potential usefulness	Comparison of whether phenomenon is emergent with respect to the differing conceptualisations of the typology.	7.1, 7.2

Table 3-4: Summary of the criteria and assessment activity for the explanatory framework for describing real-world emergents

(d) Assessment of the research

The success of the research rests on two key factors – whether it achieves its aims and objectives and whether the research design is fit for purpose. The assessment criteria for each are discussed below.

(i) Assessing the success of the research overall

Overall, the research is concerned with improving understanding of emergence, specifically, the overarching research question – *Can a broad conceptualisation of emergence lead to increased understanding of emergence?* As discussed in section 3.1.3, in the context of this research, the broad conceptualisation and its associated conceptual tools may be considered useful if it (i) provides a coherent and plausible description of the broad concept of emergence; (ii) provides an explanation for at least one of the key conflicts surrounding the understanding of emergence; and (iii) facilitates disciplinary and interdisciplinary analytical discussion regarding emergence. Table 3-5 below summaries how these criteria are used in Chapter 8, section 8.2.1 to assess whether the research can reasonably be judged successful.

Success criteria	Assessment activity	Section
Broad conceptualisation: (i) provides a coherent and plausible description of the broad concept of emergence;	Based on plausibility and potential usefulness of the broad conceptualisation of emergence and its elaboration through the multi-tiered typology;	8.2.1
(ii) provides an explanation of at least one key conflict surrounding understanding of emergence;	Based on explanation of ongoing difficulty in definitive definition due to emergence being a fuzzy concept;	8.2
(iii) facilitates disciplinary and interdisciplinary analytical discussion regarding emergence.	Based on analytical capabilities illustrated in Chapter 7, section 7.3.	8.2

Table 3-5: Summary of the criteria and assessment activity relating to the success of the research

(ii) Assessing the research approach

The research approach consists of three broad strategies – pragmatic, interdisciplinary and conceptual analysis strategies. The following issues pose the most significant threat to the fitness of the research strategy and methods adopted.

The core features of a pragmatic research approach is that the research (i) uses real-world examples and conflicts to explore the research problem and (ii) evolves, as methods and proposed outputs are revised as inconsistencies become apparent. The main issues concerning a pragmatic approach are then that (i) the examples and conflicts used to explore the research domain, which form the key focus of the pragmatic approach, should sufficiently span the research domain and (ii) the research manages to remain focussed on its goals during the revisions.

As discussed in section 3.1, the core features of the interdisciplinary approach adopted in this research is that it is focussed on interdisciplinary informed conceptual problem solving and that it generates both transdisciplinary and multiple disciplinary outputs. The research outputs have been specifically designed to address the tension between transdisciplinary and disciplinary knowledge. From the discussion of interdisciplinarity in section 3.1.2(b), I would contend, the most significant potential issues regarding the actual interdisciplinary method employed are how to: (i) actually achieve interdisciplinarity given the single researcher remit of a PhD and (ii) ensure that unsound conclusions are not arrived at due to lack of full understanding of the various thought domains that have given rise to the varying conceptualisations.

The principle issue associated with conceptual analysis is that its outputs are not provable.

These potential limitations of the research approach and how and where these are assessed are summarised in Table 3-6 below.

Potential limitation	**Assessment activity**	**Section**
Pragmatic strategy: (i) choice of examples and conflicts aided exploration of problem domain; (ii) research remained focussed.	Illustration of how potential limitation has been minimised as far as reasonably possible	8.2.2
Interdisciplinary strategy: (i) can single researcher undertake interdisciplinary work? (ii) lack of understanding of different disciplinary thought domains	Illustration of how potential limitation has been minimised as far as reasonably possible	8.2.2 8.2.2
Conceptual analysis: outputs are not provable	Discussion of potential impact on findings	8.2.2

Table 3-6: Summary of the limitations relating to the success of the research and how their impact is assessed

The four stage assessment process

As Figure 3-3, p112 illustrates, the preceding criteria for the plausibility ad potential usefulness of the conceptual proposals and research (Table 3-2-Table 3-6) are assessed in a four stage process.

The first assessment stage deals with assessing the plausibility and limitations of the conceptual proposals. Using the plausibility criteria identified in Table 3-2 (criteria 1-3), Table 3-3 (criteria 1-3) and Table 3-4 (criteria 1-3), each conceptual development is assessed, in sections 4.2.1, 5.2.1 & 6.2.1 respectively. Assessment is completed on individual conceptual proposals before the next is developed to ensure the conceptual foundations upon which subsequent developments are based are plausible.

Once the conceptual developments have all been completed, assessment of the usefulness of the conceptual proposals is undertaken in Chapter 7. This is achieved by using the proposals to undertake some analysis regarding emergence and real-world emergents. As illustrated in Figure 3-3, p112, this is split into two – stages 2 & 3. In stage 2, the explanatory framework is used to develop descriptions of seven real-world emergents in section 7.1, the success of which confirms the potential usefulness of the framework. The real-world phenomena – the property of being a circle, thermodynamic properties, the smell of ammonia, the functionality of a machine, the World Wide Web, life and mind – are selected from the list of classic examples of Chapter 2, section 2.2. Following Doty and Glick's (1994) advice, the example emergents are selected to include both typical and interesting cases. In particular, they aim to capture key explanatory problems regarding emergence, which are detailed in Table 7-22, p249. Not all of the original classic examples are reconsidered here, primarily for practicality reasons. The structure of the universe is excluded as adequate description of its emergence would involve consideration of many different instances of emergence over the millennia. Patterns and stripes are not considered simply because their descriptions do not reveal anything interesting in addition to those of the seven selected examples. Finally, social capital is omitted here as it is considered separately in stage 3.

Before these descriptions can be used in stage 3 where conceptual analysis designed to assess the potential usefulness of the conceptual tools is undertaken, the quality of the descriptions must first be assessed. This is achieved, in section 7.2, through two activities. First, whether the descriptions generated by using the explanatory framework have led to improved clarity in areas that were proving problematic is considered. As discussed in Chapter 2, subsection 2.4.4, we are dealing with phenomena which may be intrinsically difficult to explain, thus the emphasis here is on improved clarity (Table 3-4, p132, criteria 4-6) and not that the problem is fully resolved. The second activity undertaken is to consider the limitations of the descriptions and how they are developed – i.e. the explanatory framework. Here the implications of limited knowledge, researcher bias, multiple perspectives and difficulty in ensuring the framework is consistently applied are considered.

In section 7.3, stage 3 of the assessment process then uses these real-world grounded explanatory descriptions, to analyse the validity of the broad conceptualisation and to assess whether the multi-tiered typology can be usefully used to undertake a range of analytical activities. While a range of different analyses could be undertaken, the focus is on three key tasks which will help further assess the three conceptual proposals. In subsection 7.3.1, cross-analysis of the key characteristics and dimensions of the seven example emergents (Table 3-2, p129, criteria 1,3) is undertaken in order to further assess the broad conceptualisation of emergence. Then, in subsection 7.3.2, the seven example descriptions are loosely matched using the multi-tiered typology. This categorisation of the seven descriptions is then used to assess whether the multi-tiered typology can support comparison and generalisation activities (Table 3-3 , p131, criterion 4). This is followed by assessment of its ability to support 'prediction' and extrapolation. It should be noted that while the broad claim, argued in section 3.2.2(b) and Chapter 6, is that the multi-tiered typology can be used to predict the characteristics of new emergents of a given broad type, identification of brand new emergents is out of the scope of this research. What is actually assessed, therefore, is the ability of the multi-tiered typology to infer the emergence-related characteristics of a real-world phenomenon – social capital – which was not one of the seven example descriptions. This 'prediction' is then checked by applying the descriptive framework to a real-world study of social capital. Social capital was chosen because it was one of the original classical examples of emergence selected in Chapter 2 and this had also been the subjected of a separate study of emergence in complex learning communities which I had undertaken. Details of this study can be found in McDonald (2005). Full details of exactly how this 'prediction' and the comparison, generalisation and extrapolation assessments are undertaken is described in section 7.3.2 as are the results of these assessments of the potential usefulness of the multi-tiered typology. Finally, in subsection 7.3.3, further assessment of the explanatory framework is addressed. As a claimed key advantage of the explanatory framework is that it may be used to assess the broad conceptualisation and multi-tiered typology, this advantage and hence the practical application of the framework (Table 3-4, p132, criterion 4) is assessed by considering the role of the descriptions of the example emergents and hence the explanatory framework in the preceding analyses.

The final assessment stage considers the success and limitations of the research as a whole in Chapter 8, section 8.2. As discussed in subsection 3.2.3(b) above, the research rests on two key factors – its success in achieving its aims and objectives and whether the research design is fit for purpose. The success of the research is assessed in subsection 8.2.1 by discussing how the success criteria identified in Table 3-5, p133 can reasonably be judged as satisfied by the conceptual developments of Chapter 4-Chapter 6 and analysis activities of Chapter 7. How the research undertaken answers the research subquestions, SQ-E, SQ-RW and SQ-P is also considered. Assessment of the fitness for purpose of the research involves consideration of the appropriateness of the methods used in each of the three conceptual developments and the overall strategy of pragmatic, interdisciplinary conceptual analysis. Assessment of the methods used in each of the three conceptual developments is achieved by comparing the method used with other potential approaches in subsections 4.2.2, 5.2.2 and 6.2.2 respectively. The final reflection on the research approach presented in section 8.2.2, therefore, concentrates on the success of the pragmatic, interdisciplinary and conceptual analysis strategies. This is achieved by briefly summarising each strategy followed by a discussion of how it was implemented within the research, including the extent to which it is actually employed and any difficulties that arose. The key issues, identified in Table 3-6, p134, that might affect the fitness of the strategy and their impact on the research are then considered. Assessment of the overall fitness of each strategy is then based on the extent to which the differing strategies have actually been employed and whether the key issues have been minimised, as far as is reasonably possible, given the constraints of the research.

In this section, the research methods used in this research have been described. The method is primarily based on pragmatic, interdisciplinary conceptual analysis and has three stages – extensive literature review and synthesis, conceptual development and assessment of the research. Having completed the task of this chapter, the next section summarises the chapter developments, identifying the next stage in the research process.

3.3 Summary and implications

In this chapter, the research design has been presented and discussed. The research focus which is primarily concerned with the broad problem of what emergence is, given the multiple existing and conflicting conceptualisations was discussed first. As these varying conceptualisations were shown to arise largely from different disciplinary perspectives and philosophical stances, it was decided to address this problem as a whole rather than drilling down on a particular conceptualisation. This led to an interdisciplinary approach being adopted. The problem being addressed, I argued, is a real-world conceptual problem. This led to a variation on an interdisciplinary problem solving approach being adopted, where the focus is conceptual rather than a physical problem. Consideration of how to address this conceptual problem and the issues relating to disciplinary and interdisciplinary knowledge led to the broad thesis of the research – that a broad conceptualisation which forms a transdisciplinary epistemological bridge will enable researchers and practitioners from different disciplinary perspectives and philosophical stances to increase understanding of emergence. This transdisciplinary bridge should support transdisciplinary and disciplinary analysis of emergence within a sound epistemological framework. Consideration of how increasing understanding might be achieved led to the identification of key criteria that the conceptual developments should satisfy. This led to the three subobjectives of this research – SO1:to develop an overarching conceptualisation of emergence that integrates and bounds the broad emergence domain; SO2: to develop an elaboration of the broad conceptualisation that (i) spans and differentiates the broad emergence domain and (ii) supports analytical discussion within both interdisciplinary and disciplinary contexts; SO3: to develop a tool for generating an explanatory description of real-world emergents which: (i) can be used to establish whether a real-world phenomenon is emergent; (ii) clarifies exactly what the 'is emergent' relation is; and (iii) includes the full range of core and key characteristics relating to the instantiation, generation and behaviour of the emergent.

The method developed to achieve these objectives was then presented. This is based on pragmatic, interdisciplinary conceptual analysis and comprises three stages: extensive literature review and synthesis, conceptual development and assessment of the developments. In stage 1, extant literature from multiple disciplines and philosophical stances is reviewed and analysed to identify the full extent of the problem domain, its dimensions and variables, points of conflict together with key classic examples of emergence that can be used to reconceptualise emergence. Stage 2 uses the findings of the extensive review and synthesis to propose three conceptual proposals regarding emergence – the broad conceptualisation of emergence, its elaboration through a multi-tiered typology of emergence and an explanatory framework to help describe real-world emergents – which address SO1-SO3 respectively. The final stage assesses the plausibility and potential usefulness of the conceptual proposals and the research itself.

This presentation of the research design concludes Part I of the thesis. Part II of the thesis presents the conceptual developments using the methods described above, building on the analysis of the extant literature that was presented in Chapter 2.

Part II

Having introduced the research, analysed the extant work on emergence to identify the contradictions and disagreements surrounding emergence and why they arise and described the research design in Part I of this thesis, Part II presents three conceptual proposals regarding the nature of emergence and how it might profitably be explored. Each conceptual proposal is presented in a separate chapter (Chapter 4 – Chapter 6) which starts by introducing the proposal itself. Next, the capabilities and limitations follow by the advantages of the proposal are discussed. Each chapter ends with a summary which highlights the implications for the next step in the research.

The conceptual development begins by addressing *SO1 – development of an overarching conceptualisation of emergence that integrates and bounds the broad emergence domain.* This leads to the proposal of a broad conceptualisation of emergence in Chapter 4 which sets the conceptual scene for the work. In Chapter 5, attention is then turned to *SO2 – development of an elaboration of the broad conceptualisation of emergence which spans and differentiates the broad emergence domain and that supports analytical discussion within both interdisciplinary and disciplinary contexts.* This leads to the proposal of a multi-tiered typology of emergence which supports conceptual analysis regarding emergence. The broad conceptualisation and multi-tiered typology together provide a coherent interdisciplinary epistemological framework which outlines and elaborates the concept of emergence, thus addressing *SQ-E – what is emergence?* Attention is then turned, in Chapter 6, to *SO3 – development of a tool for generating an explanatory description of real-world emergents that can be used to (i) establish whether a real-world phenomenon is emergent; (ii) clarify exactly what the 'is emergent' relation is; and (iii) describe the full range of core and key characteristics relating to the instantiation, generation and behaviour of an emergent.* The approach adopted is to develop an explanatory framework that facilitates generation of neutral but conceptually-relevant description of an emergent, its causes and behaviour, thus offering an explanation of the emergent. This third conceptual proposal addresses *SQ-RW – how might understanding of real-world emergent phenomena be improved?* Additionally, as the descriptions developed by the exploratory framework are neutral but conceptually-relevant, I will argue that they can be used to assess independently the validity of the broad conceptualisation and multi-tiered typology.

Together the three chapters in Part II represent the conceptual development with this thesis.

Chapter 4 A broad conceptualisation of emergence

Having reviewed and analysed the existing approaches to emergence, their conflicts and the range of claimed key characteristics, attention is now turned to the development of a broad conceptualisation of emergence. As discussed in Chapter 1 and Chapter 3, the rationale for the broad conceptualisation is to examine whether the full range of conceptualisations of emergence can be utilised to shed new light on emergence. Further, as discussed in Chapter 3, this is approached from a conceptual basis rather than a simple comparison in order to bring rigour to interdisciplinary discussions and lay bare what generalisations might be plausibly made regarding emergence. Examination of the issues relating to disciplinary and interdisciplinary knowledge in Chapter 3, section 3.1 led to the adoption of an epistemological framework approach that provides a bridge between interdisciplinary and disciplinary understanding. This is to be realised through an overarching component which contains the abstracted core transdisciplinary understanding regarding emergence and a more detailed component which elaborates the various conceptualisations which arise from the different thought domains. This chapter then addresses subobjective *SO1 – development of an overarching conceptualisation of emergence that integrates and bounds the broad emergence domain* by proposing and analysing such a broad conceptualisation of emergence.

The starting point of this chapter is to present the first conceptual proposal – emergence might usefully be understood by adopting a broad conceptualisation where emergence: (i) is an inherently fuzzy concept; (ii) is based around macro-level properties (emergents) which are not manifest in individual micro-level components in isolation; and (iii) encompasses ontological, epistemological and complexity 'dimensions'. As discussed in Chapter 3, subsection 3.2.2(a), this is arrived at through the analysis of the literature in Chapter 2, section 2.4 and consideration of the need, discussed Chapter 3, section 3.1, for a high-level abstraction which integrates and bounds what is meant by the broad conceptualisation of emergence within the context of a sound epistemological framework for supporting transdisciplinary and disciplinary discourse regarding emergence. This will be shown to offer a plausible high-level conceptualisation of emergence in its broadest form, satisfying the conditions for plausibility – it is epistemologically sound, captures broad but normative usage of the concept and identifies (useful) dimensions of the concept – which were identified in Chapter 3, subsection 3.2.3(a). Further, this broad conceptualisation, it will be argued, has the advantage that it allows the various existing conceptualisations to be legitimately understood as one fuzzy and micro-macro concept with multiple dimensions. As will be shown, this is a significant advantage which has three important implications for this research and for understanding emergence in general. Firstly, it offers a plausible means of resolving the ongoing definitional or conceptualisation disputes that seem to have peppered discourse on emergence to date. Secondly, it allows us to integrate existing conceptualisations under one epistemologically 'sound' framework. This is crucial to being able to integrate ideas and findings from differing disciplinary and philosophical though domains while continuing to ensure sound analytical foundation. Finally, by establishing the conceptual domain of emergence, which I will argue consists of ontological, epistemological and complexity dimensions, this allows us to clarify what type of knowledge we might expect to develop about the concept and what types of activities might be most profitable in the quest to improve understanding of emergence. This first conceptual proposal – the broad conceptualisation of emergence – therefore contributes to *SQ-E – what is emergence?*

The chapter proceeds as follows. First, in section 4.1, the first conceptual proposal – the broad conceptualisation of emergence – is presented. Its plausibility and limitations, followed by its advantages, are then discussed in section 4.2. The chapter concludes in section 4.3 by summarising findings and identifying the next stages in the research process.

4.1 The broad conceptualisation of emergence

As noted in Chapter 3, subsection 3.1.4, the objective of the broad conceptualisation (*SO1*) is *to develop an overarching conceptualisation of emergence that integrates and bounds the broad emergence domain.* As described in Chapter 3, subsection 3.2.3(a), three key points which the broad conceptualisation needs to address can be extracted from the conclusions of the review of emergence in Chapter 2, section 2.5. Firstly, the multiple overlapping conceptualisations suggest a certain degree of conceptual fuzziness. Secondly, there are no distinguishing key characteristics save the general idea that emergence concerns a micro-macro relation and novelty, which the review identified as central to the majority of definitions of and approaches to emergence. Thirdly, emergence may have ontological, epistemological and complexity components. The other key points regarding the apparent nature of emergence highlighted in Chapter 2, section 2.5 – whether it is synchronic or diachronic and the different kinds of key characteristics – relate to more detailed conceptualisation and will be the subject of investigation in subsequent chapters, as I further elaborate the conceptualisation of emergence.

These three key points lead to the following conceptual proposal which is the central tenet of this research:

Emergence might be profitably understood by adopting a broad conceptualisation where emergence:

(i) is an inherently fuzzy concept;

(ii) which is based around macro-level properties (emergents) which are not manifest in individual micro-level components in isolation;

(iii) encompasses ontological, epistemological and complexity dimensions.

Where:

- the micro-level system components may or may not be interconnected;
- 'not manifest' may be a result of the ontological status of the property or epistemological considerations such as the scope or resolution of the observation of the emergent.

The broad conceptualisation provides a useful starting point from which more detailed conceptual proposals and tools relating to the nature of emergence can be develop. At this stage in the research it deliberately tells us little about the nature of emergence save that it is fuzzy, concerns a micro-macro relation and may have multiple dimensions; rather it provides an umbrella under which deeper investigation of emergence can take place. The next section considers in detail the plausibility, limitations and advantages of the broad conceptualisation over other conceptualisations of emergence.

4.2 Discussion of the broad conceptualisation of emergence

Having proposed the broad conceptualisation where emergence may be profitably understood as (i) an inherently fuzzy concept, (ii) which is based around macro-level properties (emergents) which are not manifest in individual micro-level components in isolation and (iii) encompasses ontological, epistemological and complexity 'dimensions', attention is now turned to analysis of this first conceptual proposal. Firstly, in subsection 4.2.1 the plausibility and limitations of each criteria of the proposal are examined. This is followed, in subsection 4.2.2, by consideration of the advantages of the broad conceptualisation in relation to other approaches.

4.2.1 Plausibility and limitations of the broad conceptualisation of emergence

The rational for the broad conceptualisation of emergence is to integrate and bound existing conceptualisations in a coherent way. If this can be achieved then we may be able to engage in sound analysis of emergence across the extant extensive body of knowledge on the subject. As is argued in Chapter 3, subsection 3.2.3(a) section, if the broad conceptualisation is to be fit for purpose, then it should satisfy the following criteria: (i) be epistemologically sound; (ii) capture the broad but normative usage of the concept; and (iii) identify the dimensions of the concept. This subsection considers the extent to which the broad conceptualisation satisfies each of these requirements. Each condition is considered in turn. The subsection ends by summarising what might be concluded regarding the fitness of the broad conceptualisation and the implications of the broad conceptualisation for the research.

Epistemologically sound

The epistemological soundness of the broad conceptualisation – that it can validly encompass differing perspectives on emergence – stands or falls on its claim that emergence is a fuzzy concept – criterion (i) of the broad conceptualisation. Fuzzy concepts are a well-recognised phenomenon (Wittgenstein 1954, Rosch 1975, Laurence and Margolis 1999, Davis 2005). As current evidence suggests fuzziness arises from how we cognitively acquire understanding of a concept (Rosch 1975), it is, I would suggest, reasonable to consider that fuzzy concepts are valid meta-level epistemological concepts – i.e. they are what I have termed epistemologically 'sound'. Thus, the key question is – is it valid to consider emergence as fuzzy? Fuzzy concepts, in the intrinsic Wittgensteinian sense that is being used here, are not purely the result of imprecise conceptualisation. For example knowledge and love are two everyday concepts which are inherently fuzzy. While knowledge or love might be adequately defined or explained in a particular context, there is no generally agreed conceptualisation which is universally applicable. Two key criteria of inherently fuzzy concepts can be identified. Firstly, the edges of the concept appear fuzzy and there are no necessary and sufficient conditions that can be used to define such a concept (Wittgenstein 1954). Secondly, for the fuzzy concept to be useful, it is also important to ensure that it captures a useful concept, be it an abstracta or real object. In other words, the fuzziness is not just a result of the definition of the concept being expanded beyond its usefulness – conceptual stretching or conceptual straining (Davis 2005). Whether emergence satisfies these two criteria is considered below.

Assessing whether or not there are necessary and sufficient conditions for categorising phenomena as being representative of a particular concept is not trivial. Markusen (1999) suggests empirical testing of 'fuzzy' be carried out by determining whether a sample of researchers each comprehends and employs the concept in a similar fashion. Corning's (2002) empirical survey, mentioned in Chapter 1, section 1.3, supports that this is not the case for emergence. However, I would argue Markusen's test only assesses whether there are multiple conceptualisations and not whether the concept is intrinsically fuzzy in the Wittgensteinian sense. For example, it could be that it is in fact multiple distinct concepts that simply have the same tag. However, I would argue that it is plausible that emergence is indeed intrinsically fuzzy for two reasons. Firstly, the work of the early British emergentists displays a lack of commonly agreed necessary and sufficient conditions despite applying the concept to similar real-world phenomena. Thus the concept of emergence was plausibly fuzzy even before complexity science adopted the concept of emergence. Secondly, subsequent conceptualisations, while different, appear to be related. For example, the fact that philosophical approaches are beginning to adopt some complexity science perspectives – (Bedau 1997, Bedau 2002, Collier and Muller 1998) – and vice versa – (Bar-Yam 2004, Ryan 2006) – suggests that the concept is not overstretched. Thus, the fuzziness appears to be neither a result of multiple distinct conceptualisations nor overstretching.

The potential limitation is that the fuzziness may of course simply be a result of lack of understanding and it may eventually be possible to agree necessary and sufficient conditions for emergence. While this possibility must be acknowledged, it should be noted, many apparently intrinsically fuzzy concepts continue to resist 'universal sharpening' despite significant study of definitions, categorisations and concepts (Rosch 1973, Rosch 1975, Fodor 1975, Medin 1989, cited in Laurence and Margolis 1999). Thus, current evidence suggests that we certainly should not assume that we will be able to sharpen a fuzzy concept. Indeed, current theories of concepts such as proto-type theory suggest that fuzziness is an inherent feature of how concepts are acquired psychologically (Laurence and Margolis 1999). The best that can be said is that we are unable to distinguish which concepts may be sharpened and which may not. Therefore, I would argue, the question of whether emergence will ever be universally sharpened is moot. Thus, conceptualising emergence as fuzzy is indeed plausible and hence epistemologically 'sound'. The question for the rest of this thesis is – is it a useful conceptualisation?

Captures broad but normative usage

The idea that emergence concerns a macro-micro relation was identified in the analysis of Chapter 2, subsection 2.4.3, as core to the majority of conceptualisations of emergence. The exception being, conceptualisations such as the product of surprise alone (Roland et al. 1999) which, as I argued in Chapter 2, subsection 2.4.3, are not sufficiently discerning as they are based on phenomenological aspects and so are not sufficiently analytical to contribute significant insight. Thus, criterion (ii) which states that emergence is based around macro-level properties (emergents) which are not manifest in individual micro-level components in isolation, may be said to go some way towards plausibly capturing the normative sense of emergence. This plausibility may be further examined by considering whether it includes intuitive examples of emergence but excludes phenomena which are intuitively not emergent. The classic examples of emergence from Chapter 2, section 2.2 are used below to assess plausibility, followed by a discussion on limitations.

As the analysis of these examples summarised in Table 4-1 below illustrates, the intuitive putative examples of emergence of Chapter 2, section 2.2 fit within criterion (ii) of the broad conceptualisation. Of particular note, is the fact that criterion (ii) covers the problematic case of thermodynamics. In this case, the macro-property is a function of the observer, be it a thermometer or human senses, but as we are allowing both ontological and epistemological emergence, this is not problematic.

Example	**Intuitively emergent**	**Micro components**	**New macro property**	**Satisfies criterion (ii)**
Mind	Yes	Neurons and synapses	The mind	Yes
Life	Yes	Chemicals	Reproductive cells	Yes
Structure of the universe	Yes	Fundamental particles/strings	Stars, galaxies etc	Yes
Social capital	Yes	Individuals	Network of relationships that can be 'use'	Yes
Thermodynamic properties	Yes	Individual particles	Temperature, entropy	Yes
Smell of ammonia	Yes	Hydrogen, nitrogen	The smell of ammonia	Yes

Example	**Intuitively emergent**	**Micro components**	**New macro property**	**Satisfies criterion (ii)**
Patterns – Bénard Cell	Yes	Individual molecules in the liquid	Convection cells	Yes
Computational patterns	Yes	Individual cells in cellular automaton	Global behaviour of the cellular automaton	Yes
Property of being a circle	Yes	Set of continuous points	Being a circle	Yes
Function of a machine	Yes	Individual mechanical components	Function	Yes
Diffraction pattern	No	Light beam [photons]	None [Electromagnetic wave]	No [yes]
Two men in a boat	No	Two men	None	No

Table 4-1: Analysis of correspondence of criterion (ii) of the broad conceptualisation of emergence to the examples of Chapter 2, section 2.2

As Table 4-1 above illustrates, the examples of cases that intuitively are not emergence are more problematic. The 'two men in a boat' example does not qualify as emergent as the ability to cross the pond is not really a new macro-level property. This is because the two individual rowers could also theoretically cross the pond, one after the other, in time and location. This is the same as the case of the weight of ten apples together which is not an emergent property as it is the same as the sum of the weight of ten apples – weight is manifest in the micro-level components.

The diffraction pattern example is slightly more problematic. A diffraction pattern is at the same 'level' as a beam of light – it is just a change in pattern; so by criterion (ii), it is not emergent from the beam of light. However, if we were to consider the macro-level as individual photons, then perhaps it can be said that there are micro- and macro-levels – the macro-level being where light behaves as a wave as opposed to individual light particles. Indeed, light exhibits quite different properties at these differing scales of observation. However, that would be equally true of the beam of light before and after the diffraction event. So the diffraction pattern itself is nothing special. It is the wave form that is emergent by criterion (ii) of the broad conceptualisation rather than the pattern itself.

Three potential limitations of normative coverage can be identified. Firstly, there is a danger that criterion (ii) may not be sufficiently discerning and thus include phenomena that are not intuitively emergent. However, as the rejection of 'two men in a boat' and the diffraction pattern indicate, a wide range of multi-part phenomena can be reject. For example, any 'simple sum' phenomenon where the macro-level property is a sum of a micro-level property is excluded. Likewise, simple novelty such as the breaking of a rock into two smaller rocks or flipping a coin from heads to tails is excluded as it is not a result of multiple micro-level components. In the first instance, the micro-level system component is physically changed and in the second, there is only one component – the coin. A more detailed and discerning description of emergence would significantly reduce this limitation. But, I would argue, a more discerning definition would not be appropriate given the stated aim of using existing conceptualisations and conflicts to investigate the nature of emergence. Secondly, as the above discussion of diffraction patterns illustrates, it may be necessary to further elaborate in what sense a particular phenomenon might be either compatible with, or excluded by, criterion (ii). This does not detract from the plausibility of the broad conceptualisation, only its potential usefulness and is in line with the pragmatic approach adopted within the research. Thirdly, it should be acknowledged that others may have a different interpretation of whether a phenomenon is emergent or not due to differing perspectives of what the micro and macro components are. For example, where the property of the ability to cross the river lies may be interpreted differently or a coin might be viewed as a system with two micro-level components – its two sides. However, I would argue that the interpretation should be compatible with everyday sense of the object under discussion. The best that can be said at this stage of the research is, the interpretation discussed in the preceding section describes what is meant by emergence within the context of this research.

Identifies the key dimensions of the broad concept of emergence

Criterion (iii) of the broad conceptualisation suggests that this may be profitably achieved by considering ontological, epistemological and complexity dimensions. For this to be valid, it was argued in section 3.2.3(a) that it might be reasonable to expect that the dimensions: (1) provide coverage of the conceptual domain while emphasising the different motivations for the concept; (2) are sufficiently distinct to contribute differing insight; and (3) provide a degree of overlap to aid validity of conclusions. The degree to which the three dimensions satisfy these three conditions is discussed below.

Firstly, as the review of Chapter 2 illustrates, emergence is associated with macro-level phenomena that are difficult to explain in terms of their component micro-level parts. The review identifies three possible rationales for this difficulty – that emergents are at a fundamentally different ontological level from their component parts; that emergence depends on our perception and existing knowledge; and that emergence is a product of non-linear dynamics (complexity) – which are respectively the motivation for the ontological novelty, epistemological novelty and product of a complex system approaches to emergence identified in Chapter 2. Thus, I argue, the ontological, epistemological and complexity dimensions provide coverage of the conceptual domain while emphasising the different motivations for the concept.

Secondly, as ontology is concerned with understanding of the nature of phenomena and epistemology is concerned with understanding of our knowledge regarding phenomena, these are clearly different undertakings, both of which are required if we are to truly understand a phenomenon. A complexity perspective is concerned on the other hand with how relationships between phenomena change over time. It could be argued that this makes complexity part of ontology. However, I suggest it is appropriate to include both a general ontological and complexity dimension as this accentuates three important points of conflict identified in Chapter 2, section 2.4 – a key component of the pragmatic research approach adopted in Chapter 1. (1) Until recently at least, ontological perspectives presupposed that emergence has a synchronic nature. However, the synchronic versus diachronic nature is a key conflict identified in section 2.4. Inclusion of a complexity dimension forces a dynamic perspective to be considered. (2) The exact ontological nature of emergence itself is subject to dispute. As discussed in Chapter 2, section 2.4, this arises from different philosophical stances as to the nature of reality. By including a specific complexity dimension, I would argue, this forces consideration of a spectrum of degrees of reducibility. (3) Whether emergence is ontological or epistemological in nature is an ongoing conflict. Given the lack of clarity, I would argue that we should remain open to the possibility that it is a complex interaction of epistemological and ontological factors that gives rise to emergence. Again, without a specific complexity dimension the effects of this could easily be overlooked.

Finally, the discussion of the previous paragraph clearly illustrates a degree of overlap between the three dimensions. Thus, I contend, the three dimensions plausibly cover the conceptual domain surrounding emergence, identifying the types of investigation and knowledge which may prove useful in improving understanding of emergence.

Two further potential limitations of the broad conceptualisation can be identified. Firstly, a different choice of dimensions might provide better insight. As emergence is associated with difficulties in explanation and as the discussion above illustrates these three dimensions are innately associated with explaining the nature of an object, how it might be understood and its complexity, I would suggests these are a reasonable choice. Secondly, and more generally, a narrower approach to emergence might result in theoretical insight. That, however, is not the objective of this research and, I would argue, that given the current state of understanding and the advantages of interdisciplinary perspectives, this broad conceptualisation is at least something which should be explored.

Conclusions and implications regarding the plausibility of the broad conceptualisation of emergence

In the preceding subsections the plausibility of the broad conceptualisation of emergence was assessed with respect to the assessment criteria listed in Table 3-2, p129. This leads to the conclusion that the conceptual proposal is plausible, given the current state of knowledge at least. However, its usefulness – whether it will aid understanding is yet to be tested. The potential advantages that the broad conceptualisation offers and its implications are considered next.

4.2.2 Advantages and implications of the broad conceptualisation of emergence

The first conceptual proposal – that emergence may be profitably understood as (i) an inherently fuzzy concept, (ii) which is based around macro-level properties (emergents) which are not manifest in individual micro-level components in isolation and (iii) encompasses ontological, epistemological and complexity dimensions – forms the central tenet of this research. This broad conceptualisation of emergence is deliberately designed to capture the majority of existing conceptualisations of emergence – the excluded conceptualisations being the ones which are based on phenomenological aspects such as surprise alone and are not sufficiently discerning to consider further. The crucial aspect of this broad conceptualisation is that by illustrating it is plausible to consider emergence as a fuzzy concept, it allows the various existing conceptualisations to be legitimately brought together as one concept. This has four important implications which are discussed below, followed by a comparison with other approaches.

Firstly, the broad conceptualisation offers a plausible means of resolving ongoing definitional/conceptual disputes which seem to have peppered discourse on emergence. Rather, emergence is simply an inherently fuzzy concept where multiple, but related conceptualisations are equally valid. The important point being that these multiple views simply arise from different perspectives of the same natural phenomenon. Additionally, the broad conceptualisation is discipline and philosophical stance neutral. In particular, it makes no distinction between strongly and weakly irreducible, although it does imply that emergent phenomena cannot be simply reducible.

Secondly, it allows us to integrate existing conceptualisations under one epistemologically 'sound' framework. This provides significant advantage for the task at hand – improving understanding of emergence – as it allows us to legitimately draw on the conceptualisations and understanding from different disciplinary and philosophical perspectives of emergence within a sound epistemological framework. Within interdisciplinary discourse such sound epistemological foundation is critical as the discussions of Chapter 3, section 3.1 illustrate. Given the intersection of epistemologies inherent within interdisciplinary discourse, without such conceptual foundation, misconceptions can result (Wear 1999). Although the conceptual foundation is very broad at this stage, I would argue that it satisfies Star and Griesemer's (1989) requirements of being sufficiently robust to be used across disciplinary boundaries but plastic enough to be manipulated. For example, while the broad conceptualisation bounds the concept, capturing the normative usage, it can still be used within philosophy to examine the ontological and epistemological roots of the concept, while within complex systems it will still allow exploration of macro-level phenomena.

Thirdly, the broad conceptualisation of emergence outlines the conceptual domain – the range of application of the concept. By this I mean that by identifying the three dimensions, it allows us to narrow down at least what type of knowledge we might expect to develop about the concept and what types of approaches might be successful. For example, it tells us that trying to seek an ultimate definition is likely to be unproductive. The broad conceptualisation, therefore, offers a proto-structure upon which further more detailed investigation of the structure of the conceptual domain relating to emergence can be based. So ironically, broadening the conceptualisation and accepting the inherent fuzziness might be said to actually narrow the problem.

Finally, as the analysis of the plausibility of criterion (ii) illustrates, there is a need to further discuss specific examples to clarify how they might be considered emergent or not. As discussed in the previous subsection, the explanations of these examples effectively bound the interpretation of emergence within this thesis. This is in effect how Wittgenstein (1954) suggests definitions be narrowed. Additionally, this alerts us to the fact that we might continue to need examples to clarify what we mean by emergence. Thus, the examples of Chapter 2, section 2.2 will be used to clarify discussions throughout the thesis.

Two alternative approaches could have been adopted. Firstly, the alternative solution to the issue of interdisciplinary rigour would be to make explicit disciplinary concepts and language (Wear 1999). This is something that I will return to in Chapter 5. However, I would argue at this stage we need to first integrate the multiple conceptualisations to establish that they all are discussing the same natural phenomenon – emergence – before we begin differentiating to explore what we can learn from the different disciplinary perspectives. Without this, we may end up back at the definitional and conceptual disputes. The broad conceptualisation, I suggest, provides this integration. Secondly, we could simply narrow the conceptualisation. However, as discussed in Chapter 1 and Chapter 3, section 3.1, this would fail to let us take advantage of the differing disciplinary and philosophical insights.

The recognition of the fuzzy nature of emergence draws on the likes of Holland (1998), Roland et al (1999), Johnson (2001) and (Kubik 2003) who have recognised the difficulties in establishing exactly what emergence is. Unlike their approaches, the innovation of the broad conceptualisation proposed here is that it embraces the inherent fuzziness to provide both an epistemologically sound basis for further investigation and, I contend, an explanation of why the definitional difficulties arise.

In this section, the broad conceptualisation of emergence proposed in section 4.1 has been analysed to assess its plausibility and limitations followed by its advantages and implications. This leads to the conclusion that the broad conceptualisation which states that emergence may be profitably understood as (i) an inherently fuzzy concept, (ii) which is based around macro-level properties (emergents) which are not manifest in individual micro-level components in isolation and (iii) encompasses ontological, epistemological and complexity dimensions, is plausible given the current state of knowledge at least. However, its potential usefulness – whether it may aid understanding is yet to be tested. The crucial aspect of this broad conceptualisation of emergence is, I argue, that by illustrating it is plausible to consider emergence as a fuzzy concept, it allows the various existing conceptualisations to be legitimately brought together as one concept. This has four important implications for this research and for understanding emergence in general. Firstly, it removes the need for ongoing definitional or conceptualisation disputes which seem to have peppered discourse on emergence. Secondly, it provides an epistemologically 'sound' framework which will enable integration of ideas and findings from differing disciplinary and philosophical perspectives, ensuring rigour. Thirdly, this in turn allows us to establish the conceptual domain of the concept, which I argued consists of ontological, epistemological and complexity dimensions. This then allows us to clarify what type of knowledge we might expect to develop about the concept and what types of approaches might be successful. This, I argued, will facilitate identification of profitable activities in the quest to improve understanding of emergence. Finally, there is a need to continue to use examples to clarify meaning. Having completed the task of this chapter, the next section summarises the chapter developments, identifying the next stage in the research process.

4.3 Summary and conclusions

In this chapter, a broad conceptualisation of emergence – the central tenet of this research – was developed and discussed. Drawing on the key conflicts and key characteristics identified in Chapter 2 and the requirements for an interdisciplinary understanding identified in Chapter 3, section 3.1, led to the first conceptual proposal – that emergence may be profitably understood as (i) an inherently fuzzy concept, (ii) which is based around macro-level properties (emergents) which are not manifest in individual micro-level components in isolation and (iii) encompasses ontological, epistemological and complexity dimensions.

The plausibility of the broad conceptualisation was established by considering whether it is epistemologically sound, broadly bounds the concept while retaining its normative usage and establishes the conceptual domain. The broad conceptualisation, I argued, has the advantage that it allows the various existing conceptualisations to be legitimately understood as one fuzzy, micro-macro concept with three conceptual dimensions. As I further argued, this has four important implications for this research and for understanding emergence in general. Firstly, it offers a plausible means of resolving the ongoing definitional and conceptualisation disputes. Secondly, it allows us to integrate existing conceptualisations under one epistemologically 'sound' framework, a vital requirement to ensure sound analytical discourse within an interdisciplinary environment. Thirdly, by establishing the conceptual domain of the concept which spans ontological, epistemological and complexity dimensions, it allows us to clarify what type of knowledge we might expect to develop and what types of activities might be profitable in the quest to improve understanding of emergence. Finally, as the analysis of its plausibility illustrates, there is a need to continue to use examples to clarify meaning. This first conceptual proposal – the broad conceptualisation of emergence – therefore satisfies *SO1– development of an overarching conceptualisation of emergence that integrates and bounds the broad emergence domain* and addresses *SQ-E – what is emergence?*

Thus, the broad conceptualisation provides a useful starting point from which further conceptual tools for exploring the nature of emergence can be developed. Before discussing the next step, two significant points which shall be returned to later in the thesis are highlighted. Firstly, the difficulties experienced in clarifying whether putative examples of emergence fell under criterion (ii) of the broad conceptualisation or not indicate that, in line with Wittgenstein's (1954) observation on fuzzy concepts, we will need to continue use examples for clarification. Secondly, while I have argued that the broad conceptualisation is plausible, the critical question of whether it actually has the potential to help us improve understanding of emergence is still to be addressed. How and whether this can be substantiated will be returned to in Chapter 7 and Chapter 8. But first, in the next chapter, attention is turned to elaboration of the broad conceptualisation. To achieve this, I return to the differing conceptualisations identified in the review of Chapter 2 to investigate how these might help support effective interdisciplinary discourse to explore the broad conceptualisation of emergence.

Chapter 5 Elaborating the broad conceptualisation of emergence

Having proposed an overarching broad conceptualisation of emergence, attention is now turned to the more detailed elaboration of the conceptualisation. As discussed in Chapter 3, section 3.1, this elaboration forms part of the overall epistemological framework designed to enable disciplinary knowledge regarding emergence to be leveraged within both disciplinary and transdisciplinary contexts. As discussed in subsection 3.1.3, truly transdisciplinary knowledge can be highly abstract and may actually fail to leverage the advantages that exposing different thought domains may bring. The elaboration of the broad conceptualisation, therefore, aims to make explicit the conceptualisations from different thought domains – i.e. to make explicit existing conceptual foundations to underpin and focus discussions within an overarching epistemological framework. Without such a means of focussing and underpinning the discourse, confusion is likely to prevail and the blank slate of the broad conceptualisation is likely to remain as such, with no progress being made on improving understanding of emergence. This chapter is, therefore, addressing subobjective *SO2 – the elaboration of the broad conceptualisation of emergence which spans and differentiates the broad emergence domain and that supports analytical discussion within both interdisciplinary and disciplinary contexts.*

The starting point is to propose that the elaboration of the broad conceptualisation of emergence be achieved through a multi-tiered typology which is based on the broad approaches to emergence and their conceptualisations which were identified in the literature review of Chapter 2, section 2.3. As discussed in Chapter 3, subsection 3.1.3(b) this typology approach is adopted because in undertaking the literature review a typology of approaches to emergence had effectively been developed and this typology satisfied the general criteria for the elaboration of the broad conceptualisation captured in SO2 above. Further, as discussed in subsection 3.1.3(b), typologies have long been used as a tool to support communication and analytical discussion, including analysis of differences between groups of phenomena, extrapolation of characteristics and prediction regarding where similar phenomena might be found. However, such abilities depend on the design of the typology, with well chosen and internally homogeneous definition of types critical to supporting more explanatory activities. In particular, if a typology is to support both transdisciplinary and disciplinary discourse, I argued in 3.2.3(b) that the typology should be satisfy the following three criteria – that it adequately spans the domain of interest, is locally consistent and globally coherent, and is conceptually founded. The purpose of the typology is to support analytical interdisciplinary and disciplinary discourse and it thus forms a tool for improving understanding of emergence. Further, it will be argued, this has three additional key advantages over other existing typologies of emergence. Firstly, it elaborates the broad conceptualisation and thus provides a more detailed description of what is meant by emergence. Secondly, it provides a parsimonious framework for developing and conveying shared meaning of emergence within an interdisciplinary context. Thirdly, it provides a means of identifying boundary objects and their characteristics – objects which form a key focus for exploring problems in interdisciplinary discourse. The second conceptual proposal – the multi-tiered typology of emergence – thus further addresses *SQ-E– what is*?

The chapter starts, in section 5.1, by proposing a new multi-tiered typology which, I will claim, facilitates communication and analytical discourse in an interdisciplinary context. The capabilities and limitations of the proposed typology, followed by its advantages over other methods and existing typologies are then discussed in section 5.2. The chapter concludes, in section 5.3, by summarising the developments and identifying the next stage in the research process.

5.1 A multi-tiered typology of emergence

This section presents a new multi-tiered typology of emergence which, it is argued, supports interdisciplinary and disciplinary analysis of emergence. The typology is presented first, followed by advice on how it might be used.

The multi-tiered typology

The typology proposed in Figure 5-1 below emerged, as discussed in Chapter 3, subsection 3.1.3(b), from the extensive review of emergence which was presented in Chapter 2, section 2.3.

Figure 5-1: Multi-tiered typology of emergence

As Figure 5-1 illustrates, the multi-tiered typology is based, at its top tier, on the three basic approaches to emergence identified in Chapter 2, section 2.3 – //Ontological_novelty, //Epistemological_novelty and //Product_of_complex_system. (Note: '//' denotes top tier type and '/' will be used to distinguish between types and subtypes.) Each top tier type (approach) is then subdivided, in tier 2, into different views of what an emergent is, based again on the review of Chapter 2, section 2.3. So emergents might be: either /Macro_property or /Macro_entities|rules in ontological novelty approaches; /Macro_patterns-structure|processes – in product of complex system approaches; simply /Macro_phenomenon – encompassing all of the latter – in epistemological novelty approaches. These views are then subdivided again, where appropriate, in tier 3 into particular sub-views. Each tier 3 label – e.g. */Macro_entity_causal_power*, */Downward_causation*, */Phenomenological* etc. – is simply the label for the view and therefore, as in the case of *//Epistemological_novelty/Macro_phenomenon/ Relative_to_theory|knowledge*, it may have multiple associated key 'essence' characteristics. The key characteristics, again based on the review in Chapter 2, section 2.3, are presented in tier 4. For simplicity, they are not directly connected to the tier 3 nodes because for example *Irreducibility* might be the key characteristic of multiple sub-nodes as illustrated in *//Ontological_novelty/Macro_entity|rules/Hierarchy*, *//Ontological_novelty/Macro_entity|rules/Macro_entity_causal_power* and *//Ontological_novelty/Macro_entity|rules/Downward_causation*. The identified key characteristics are 'subdivided'[52] into different varieties in tier 5. For example, as discussed in subsections 2.3.1 and 2.4.3, irreducibility may be viewed in terms of *Strong*, *Weak* or *Nominal* irreducibility. And in the case of non-deducibility, *Resolution*, and *Scope* identify that non-deducibility may be relative to any of these factors. Thus, it is important to note that these 'varieties' of the key characteristics are not of the same subtype across the multi-tiered typology. Each of the varieties is included because it is core to a particular perspective on emergence. Further, the key characteristics themselves are quite diverse. As discussed in Chapter 2, section 2.4, this is due to the fact that approaches to emergence have arisen from a number of very different drivers.

Thus, as the path *//Ontological_novelty/Macro_entity|rules/Macro_entity_causal_power* in Figure 5-1 captures, in ontological novelty approaches to emergence, one view is that the

[52] This subdivision is not necessarily exclusive.

key characteristic of emergence is its macro entity causal powers (Baas and Emmeche 1997) while another, captured by path *//Ontological_novelty/Macro_entity|rules /Downward_causation*, is that downward causation affects its constituent parts (Campbell 1974). Likewise, in Figure 5-1 path *//Product_of_complex_system/Macro_patterns-structure|processes/Constraints* captures that within 'product of complex product' approaches to emergence, the key characteristic of emergence might be viewed as arising from constraints (Polanyi 1968, Holland 1998, Atay and Jost 2004, Bar-Yam 2004) or dynamics (Goldstein 1999, Corning 2002). The typology therefore builds on the existing repository of knowledge regarding emergence.

Two important points are noted before proceeding further. Firstly, the construction of the types/subtypes in this way is critical to internal consistency. This is what Kluge (2000) is arguing for when she says that the types/subtypes of a typology must be built on meaningful relations – that is they must make sense to the outside world. In this case the meaningful relation is the relation between emergent and key characteristics within a given conceptualisation. An important consequence of this structure is that care must be taken when making comparisons as different leaves may be of radically different forms – i.e. the subtypes may be radically different. This is not problematic for the typology *per se* as the subtypes all relate to the overarching conceptual space. Indeed these differences and why they arise is one of the issues that the typology is designed to explore. Secondly, the proposed typology is part of a pragmatic investigative approach and therefore it is presented as a plausible and potentially useful tool to help investigate emergence. As such, there is no presumption of comprehensiveness or uniqueness. Having established these 'terms and conditions of use', how the multi-tiered typology might be utilised to support communication and analytical discussion within an interdisciplinary discourse, with multiple philosophical perspectives, is briefly explained below.

How to use the typology for conceptual analysis

The multi-tiered typology is a typology of *approaches* to emergence. Strictly, it is used to analyse and potentially classify approaches to emergence and not real-world emergent phenomena. As the typology is idealised, there is no requirement for a particular approach to be categorised into a specific type/subtype. For example, the broad conceptualisation of emergence proposed in Chapter 4 would not fit uniquely into any of types/subtypes as a central premises (criterion (iii)) is that emergence consists of ontological, epistemological *and* complexity dimensions. However, the broad conceptualisation by design, also encapsulates all the types/subtypes. Approaches to emergence can therefore be matched to the types/subtypes within the typology in two ways. In *strict matching* a conceptualisation is matched with the type/subtype if and only if the conceptualisation is exclusively of the top tier type in nature – i.e. exclusively a product of ontology, epistemology or complexity. In *loose matching* of a conceptualisation, matching merely indicates that a conceptualisation encompasses facets related to ontological novelty, epistemological novelty or product of a complex system. Using these two forms of matching, the multi-tiered typology can be used to communicate and explore the various conceptualisations of emergence held by individuals within an interdisciplinary or disciplinary discourse.

As the multi-tiered typology is based on approaches to emergence, it can also be used to communicate and explore how *individual phenomena* might be considered emergent under differing approaches (conceptualisations). In *strict matching of emergents*, an emergent is matched with the type/subtype if and only if the emergent is exclusively of the top tier type in nature – i.e. exclusively a product of ontology, epistemology or complexity. In *loose matching of emergents,* matching merely indicates that a phenomenon has ontological, epistemological or complex systems-related contributing causal factors. Using these two forms of matching of emergents, the multi-tiered typology can be used to communicate and explore how conceptualisations relate to real-world emergent phenomena.

How these conceptual analyses may be achieved is briefly illustrated below. More detailed examples of loose matching and generalisation, communication, prediction and extrapolation applications are provided in the assessment undertaken to illustrate potential usefulness of the multi-tiered typology in Chapter 7, subsection 7.3.2.

(a) Communicating and exploring conceptualisations of emergence

The typology can be used to explore conceptualisations of emergence in four ways. Firstly, the typology may be employed to help clarify the different approaches to emergence that the various participants in the discourse bring and to explicitly share these conceptualisation amongst participants. Secondly, with recourse to the conceptual foundations of the subtypes, generalisations can be made regarding the key features of these different conceptualisations. Thirdly, new views on emergence – from literature or a new participant in the discourse – may be assigned to a type or subtype, depending on the perceived key features. This will then allow exploration of whether the new view shares other common characteristics of the conceptualisation or not. Finally, the different tiers of the typology also allow exploration of which conceptualisations share common key features. For example, strong and weak appear as leaves in several conceptualisations. By working back up the typology, the different conceptualisation of strong and weak can be explored. While its structure means that the typology cannot be used to predict a unique conceptualisation based on a claimed key feature, I would argue that the ability to predict possible conceptualisations is still useful in trying to improve understanding as it potentially exposes hidden relationships.

(b) Communicating and exploring putative emergents

The typology can also be used to explore putative real-world emergents in four ways. Firstly, the typology can be used to communicate why a participant considers the phenomenon to be emergent. So for example, by loosely matching thermodynamics into the *//Epistemological_novelty/Macro_phenomenon/Model_change/Conceptual* subtype, this will communicate that in this context it is considered emergent because the concept - language and theory in this case - does not exist at the micro-level to support it. While this could be achieved by a general description without reference to the multi-tiered typology, by presenting it within the context of the typology and why it is not a considered emergent under a different conceptualisation, it illustrates where the emergent lies within the structured conceptual domain of the broad conceptualisation. Thus, by positioning the emergent within a specific branch of the multi-tiered typology, it effectively provides a communication shortcut, as it implies its position within the conceptual domain. Secondly, by considering the general subtype to which a phenomenon might belong, it is possible to predict where other examples of emergence might lie. For example, the *//Epistemological_novelty/Macro_phenomenon/Relative_to_theory|knowledge/Non-deducible* path suggests that potential emergents might be found where the language used to describe the macro phenomena has no meaning at the micro-level. So community, which is not a concept that exists at the level of the individual, might be considered emergent in this conceptualisation. Thirdly, where a putative emergent may be assigned to more than one type, it may be used to explore whether there are hidden meaningful relationships between types or subtypes and, by comparing and contrasting features of the conceptualisation, whether this exposes key features. For example, it might be appropriate to compare *//Ontological_novelty/Macro_entity|rules/Downward_causation/Irreducibility/Strong* with *//Epistemological_novelty/ Macro_phenomenon/Model_change to* investigate whether any relation can be found. Finally, the multi-tiered typology may be used to make extrapolations based on how a new example fits into the typology. This can be achieved where there is evidence that phenomena which loosely match to a specific intersection of types/subtypes share a common set of characteristics. In such cases, I argue, it is reasonable to extrapolate that other phenomena which also match the specific group of types/subtypes may also share this set of characteristics.

In this section a multi-tiered typology of emergence, based on the three general approaches to emergence and their subtypes that were identified in Chapter 2, has been proposed and advice on its potential application provided. The ability to describe conceptualisations and expose their differences, combined with the putative emergent based investigation which can expose both relations between conceptualisation and key features and facilitate prediction and extrapolation suggest the multi-tiered typology supports analytical discourse and offers a means to help explain the broad concept of emergence. The next section examines in detail the capabilities, limitations and advantages of the multi-tiered typology.

5.2 Discussion of the multi-tiered typology of emergence

Having proposed a multi-tiered typology of emergence which is designed to aid focussed and conceptually founded interdisciplinary discussion and exploration of emergence, this section analyses this conceptual proposal. Firstly, in subsection 5.2.1, its capabilities and limitations are analysed to assess whether the typology is 'fit for purpose'. Then, in subsection 5.2.2, the advantages of the typology in relation to other approaches are considered.

5.2.1 Capabilities and limitations of the multi-tiered typology

As illustrated in the previous section, the multi-tiered typology can in principle be used to support interdisciplinary communication and analytical discussion of both conceptualisations of emergence and putative emergents. However, for there to be reasonable confidence in the effectiveness of the communication and validity of analysis which it is used to support, it is argued in Chapter 3, subsection 3.2.3(b), that the multi-tiered typology should satisfy the following conditions: (i) it adequately spans the domain; (ii) it is locally consistent and globally coherent and (iii) it is conceptually founded. This subsection considers in turn the extent to which the typology satisfies these requirements. The subsection ends by summarising what might be concluded regarding the fitness of the multi-tiered typology.

Domain coverage

For the multi-tiered typology to be a potentially useful tool, it is argued in subsections 3.1.3(a)(i) and 3.2.3(b) that it must adequately span the domain of emergence. As discussed, this entails ensuring not only that the full range of conceptualisations of emergence consistent with the broad conceptualisation can be accommodated within the typology, but also that the types differentiate interesting cases. The extent to which the multi-tiered typology achieves each of these subrequirements is considered below, followed by a discussion on limitations.

The multi-tiered typology is designed to capture the three general approaches to emergence and the different flavours of conceptualisations within them that were identified as part of the review of emergence discourse presented in Chapter 2, section 2.3. It is synthesised from this review, using conceptualisations consistent with the broad conceptualisation of emergence adopted in Chapter 4. Coverage was checked by ensuring that all the literature cited in the review that is consistent with the broad conceptualisation could be loosely matched to types/subtypes within the typology.

As subsection 3.2.3(b) recommends, the typology should highlight the 'interesting' cases of the domain. Doty and Glick (1994) advise that these are the 'extremes' of the domain. Three types of extremes can be identified. Firstly, as the broad conceptualisation of emergence identifies three dimensions to emergence – ontological, epistemological and complexity – these can be used to define three corresponding extreme types – wholly ontological, wholly epistemological and wholly complexity based. As these in turn are the basis for the three top tier approaches to emergence – ontological, epistemological and complex product – the typology clearly covers these extremes. Secondly, I would argue that the claimed key characteristics of emergence also identify extreme cases as these characteristics form the basis of the variations in conceptualisations of emergence, be they concerning generation, meta-relational or causal power. As the subtypes within the typology are based on claimed key characteristics, this means that such extreme cases are captured by the multi-tiered typology. Finally, as the rationale for the review is to analyse what is meant by emergence and why there is confusion, I would argue that the differing rationales for investigating emergence and the areas of conflict which were identified – philosophical stance, synchronic versus diachronic approaches, different key characteristics – also highlight interesting cases – i.e. where the 'conceptual discontinuities' lie. The ability to capture the conflicts is assessed by checking that the 'sides' of known conflicts appear as different subtypes. The results of this assessment are provided in Table 5-1 below, illustrating that the conflicts can be adequately highlighted.

Summary of 'conflicts' which should be explored	**How the multi-tiered typology highlights the conflicts**
Ontological versus epistemological	*//Ontological_novelty* and *//Epistemological_novelty* top tier types
Degree of irreducibility of emergents	Strong and weak subtypes
Multiple purposes of investigation of emergence	Different top tier types correspond to different rationales for investigating emergence
Logic (synchronic) versus dynamic (diachronic) nature of the emergence process	*//Ontological_novelty* and *//Epistemological_novelty* top tier types represent interpretation of emergence as a logic process; *//Product_of_complex_system* top tier represents interpretation of emergence as a dynamic process
The key characteristics of emergence – macro-level irreducibility, causal powers, improved predictability etc	The differing branches of the top tier types correspond to different key characteristics

Table 5-1: Analysis of the ability of the multi-tiered typology to highlight the conflicts surrounding emergence

Two limitations to domain coverage can be identified. Firstly, establishing whether there are missing conceptualisations – i.e. establishing what I do not know – is difficult. The extensive review technique, described in Chapter 3, subsection 3.2.1, should give confidence through the extent of coverage. Secondly, establishing whether there are missing 'interesting cases' is not possible. However, as the multi-tier typology types have been built using existing conceptualisations, they are conceptually based and therefore should capture the known interesting cases.

Although coverage cannot therefore be definitively established, I would argue that this best effort approach is sufficient for purpose as the pragmatic strategy adopted in this research embraces refinement of proposals in light of experience. What is important is there is reasonable conceptual or empirical data to support the original proposal. The extensive review, I contend, provides this.

Locally consistent and globally coherent

As discussed in subsection 3.1.3(a)(i) one objective of the multi-tiered typology is to support interdisciplinary and disciplinary analytical discussion. As discussed in subsection 3.2.3(b), within the context of this research this means the typology must be both locally consistent and globally coherent. The extent to which the proposed typology achieves each of these subrequirements is considered below, followed by a discussion on limitations.

There are several different interpretations of what is meant by consistent within a typology. Whittaker et al's (1998) interpretation ,which argues that a typology should be capable of consistently allocating phenomena into the same type independent of the researcher, is not applicable in this instance as there is no claim to be globally consistent. Rather, locally consistent means that within a subtype there is strong homogeneity (Kluge 2000) – i.e. all the matched phenomena possess a sufficient intersection of key characteristics. This can be achieved where there is a conceptual basis to the subtypes (Doty and Glick 1994). As the subtypes of the multi-tiered typology are based on what makes them emergent within specific conceptualisations, they will be locally consistent with the claimed key features forming the key characteristics. Thus, the multi-tiered typology can be said to be locally consistent.

For something to be coherent there should be logical or meaningful connections between its parts. Thus, in terms of the multi-tiered typology, global coherence means that there should be logical or meaningful connections between the types and subtypes. As the top tier of the typology is grouped by approaches to emergence and then subsequent subtypes by different conceptual foci within the approach and then by associated key characteristics, I would argue, this provides meaningful connections between any sub-branch and its parent. Further, provided these connections between branch and subbranches are made explicit, then it can be said that there are meaningful connections between any points in the typology. Thus, the multi-tiered typology can be said to be globally coherent.

There are three limitations relating to consistency and coherence within the multi-tiered typology which are worth noting. Firstly, within any branch or subbranch, the grouping is not a unique partition. So while in one branch two emergent phenomena might be allocated to the same subtype, in another branch they may be loosely matched differently. This is not problematic as global consistency is not required of a typology (Doty and Glick 1994). Secondly, as there is no global consistency and different grouping criteria at each level, distant subtypes may not be closely conceptually linked. Any analytical discussion must take care to include the various chains of links between types and subtypes. This highlights the third limitation – to make full use of the considerable analytical potential of the multi-tiered typology requires extensive understanding of the full range of conceptualisations of emergence. While this could be viewed as a disadvantage, I argue – see subsection 5.2.2 – that in fact it is a considerable asset in the quest to improve understanding of emergence. Provided these limitations are borne in mind, I contend the multi-tiered typology will support analytical discussions.

Conceptually founded

As discussed in subsection 3.2.2(b) and 3.2.3(b), the ability to employ the typology to support analytical discourse is predicated on it being conceptually founded – that is the choice of types and subtypes must have a conceptual basis (Doty and Glick 1994). The degree to which the multi-tiered typology may be said to have a conceptual basis is assessed below, followed by a brief discussion on limitations.

As discussed in Chapter 3, subsection 3.2.1, the motivation for the three approaches to emergence – ontological novelty, epistemological novelty and product of a complex system – arises from three different perspectives on why emergence is difficult to explain. These are respectively that: emergents are at a fundamentally different ontological level from their component parts; emergence depends on our perception and knowledge; and emergence is a product of non-linear dynamics. Thus, I argue, each of the three approaches and hence each of the top tier types within the typology has a conceptual basis. Additionally, as these three approaches each concentrate on one of the specific conceptual motivations for the difficulty in explanation, then I contend that this makes them idealised types in the sense of Doty and Glick (1994). Further, the subtypes of the different top tier types each focuses on specific characteristics of their respective ideal type. As these characteristics have been synthesised from an extensive body of analytical discourse on emergence, then I contend the subtypes too have a conceptual basis.

Three potential limitations to the conceptual foundation can be identified. Firstly, it could be argued that a more detailed theoretical foundation to the typology would enable better theorising. However, given the current state of understanding of emergence, this is the best that can be achieved without narrowing the scope of investigation. Secondly, Kluge (2000) argues that the types should be empiricaly grounded. As discussed in subsection 3.2.3, this is not appropriate in the context of this research. However, Kluge has a point and I would suggest for the multi-tiered typology to be plausible, at the very least it should not violate common sense or observations. Thus, following the pragmatic strategy of the research, the multi-tiered typology will need to be revised should this occur. Finally, as conceptualisations are not unique, a different choice of conceptually grounded types and subtypes might be more profitable. For example, given the argument for needing to lay bare underlying assumptions this might suggest having a philosophical foundation to the type selection. However, I argue the multi-tiered typology may be profitably based on approaches to emergence rather than philosophical foundations for two reasons. (i) At a practical level, as Christen and Franklin's (2002) survey of complex systems scientists illustrates, many complex systems scientists' interpretation of philosophical stance is not consistent with that of philosophers. (ii) I would suggest that many complex systems scientists are not interested in the minutia of which philosophical stance they have implicitly adopted. Thus, asking a complex systems scientist to select, say, between ontological or epistemological emergence would not be productive and may lead to conceptual error.

Conclusions and implications regarding the 'fitness' of the multi-tiered typology

In the preceding subsections the capabilities and limitations of the multi-tiered typology were assessed with respect to the requirements identified in section 3.2.3(b). The discussion illustrates that the multi-tiered typology plausibly spans the emergence domain, is locally consistent and globally coherent and is conceptually founded. However, the preceding assessment of the capabilities was based in large measure on the extensive review of emergence presented in Chapter 2. While the use of existing discourse lends significant weight to its plausibility, the multi-tiered typology should also be separately assessed.

5.2.2 Advantages and implications of the multi-tiered typology

As discussed in the preceding sections and subsections, the multi-tiered typology presented in section 5.1 has been designed to focus and conceptually found communication and analytical discourse within an interdisciplinary context. In addition to meeting its objectives, the typology provides three important advantages in the quest to improve understanding of emergence in all its forms. The first and most significant advantage is it further elaborates the broad conceptualisation of emergence. The second advantage is it provides a parsimonious framework for developing shared meaning of emergence within an interdisciplinary context. The third advantage is it provides a means of identifying boundary objects and their characteristics. Each advantage and its implications are discussed below in turn, followed by a comparison with other approaches.

Elaborates the broad conceptualisation of emergence

The multi-tiered typology, I suggest, provides a profitable elaboration of the broad conceptualisation of emergence. In Chapter 3, subsection 3.2.3(a), I argued that the broad conceptualisation is required to: (i) be epistemologically sound; (ii) capture the broad but normative usage of the concept; and (iii) identify the dimensions of the concept. Thus, it seems logical to expect an elaboration of the concept to not only satisfy the broad conceptualisation criteria but also to identify more of the subconcepts of the conceptual domain. Thus, for elaboration of emergence criterion (iii) becomes – capture the dimensions and subconcepts (variables) of the domain. How the multi-tiered typology satisfies these three criteria is discussed below, followed by limitation and implications.

Criterion (i) – that the multi-tiered typology is epistemologically sound- I argue can be said to hold for two reasons: (1) it is an idealised type typology and (2) it is locally consistent and globally coherent. Further, as the top tier types represent the dimensions of the conceptual domain and also capture the three main approaches to emergence identified from the extensive review, I argue the multi-tiered typology plausibly captures the broad and the range of normative usage of the concept – criterion (ii). Finally, I argue in subsection 5.2.1 that the multi-tiered typology adequately covers the conceptual domain of emergence, including dimensions, key characteristics and the interesting cases which, I contend, correspond to subconcepts within the conceptual domain. Thus, I contend, the typology elaborates the subconcepts of the conceptual domain – criterion (iii) above.

The limitations to the elaboration arise from the limitations of the typology – mainly that there may be subconcepts which have not yet identified. However, as before, this is in line with the pragmatic approach and conceptual analysis strategies. Thus, I contend, the multi-tiered typology provides a plausible elaboration of the broad conceptualisation of emergence. Additionally, as it provides a more detailed description of the broad conceptualisation I further contend that given the approach to understanding adopted in Chapter 1section 1.3, this may be said to further understanding of emergence.

Facilitates development of shared meaning of emergence

The multi-tiered typology also, I claim, has the potential to facilitate development of a shared meaning of the conceptual domain of emergence. Meaning may be thought of as comprising two components – (i) description or explanation of an object and (ii) the normative or cultural rules which prescribe its use. How the proposed typology supports these two requirements, in part at least, is discussed below, followed by limitation and implications of this potential.

Firstly, as I argue in the preceding subsection that the multi-tiered typology elaborates the conceptual domain, it clearly provides a description of emergence - the object. As this description was developed from extensive literature review and is locally consistent and globally coherent, it can be said to describe the extent, coverage and internal structure of the conceptual domain. Indeed, according to Doty and Glick (1994), the structure of typologies facilitates description in a much more parsimonious way than more traditional descriptions.

Secondly, the normative aspect of meaning captures the idea that meaning is culturally prescribed. In other words, meaning requires some system of shared rules and I would argue that this is exactly what the multi-tiered typology provides. It achieves this by making explicit the relations between the domain components. For example, the multi-tiered typology captures that weak and strong subconcepts are both used within the ontological conceptualisations of philosophy whereas constraints and dynamics are appropriate in product of complex systems conceptualisations. While the paths of the typology structure are not theoretical rules, I would argue that they provide rules of thumb, representing how these components of the domain are related. Further, as the typology is built by considering the extent and intersection of the various conceptualisations of emergence in the literature, it is reasonable to infer that the paths of the multi-tiered typology represent the normative usage. Thus, I would suggest, the typology may be viewed as capturing the normative rules of the domain. And as it can be used to compare and contrast differing conceptualisations, I would suggest it provides a means of negotiating, between a range of disciplinary cultures, the meaning of objects within the conceptual domain of emergence.

The limitation of the typology as a tool for cultivating shared meaning of emergence is that there is no description of what is actually meant by the individual terms. For example – what is meant by irreducibility or predictability? While this will be the subject of later investigation, I contend that the preceding paragraphs illustrate the multi-tiered typology is a plausible tool for sharing the meaning of the broad conceptualisation of emergence.

Identification of boundary interdisciplinary objects and characteristics

The typology also can be used to identify boundary objects (Star and Griesemer 1989) which can then be used to further focus interdisciplinary research on emergence. Boundary objects are objects which lie on a common point of intersection between disciplines and are often used to open up discussion, exposing understanding and methods held within individual disciplines (Klein 2000). The problem for emergence is there is no agreement as to whether putative emergents are indeed emergent, making choosing suitable boundary emergents difficult. While it could be argued that any putative emergent could be a boundary object as they would allow exploration of the differences of conceptualisation, they do not meet Star and Griesemer's (1989) criteria that boundary objects be both adaptable to different viewpoints and robust enough to maintain identity across them. This is critical because without these qualities Star and Griesemer maintain that that underlying tensions between viewpoints will prevent progress – the inability, in many cases, to move past the disagreement as to whether a putative emergent is actually emergent being a case in point.

However, I would argue that an emergent that can be assigned to more than one type/subtype within the multi-tiered typology is potential a boundary object, as it satisfies Star and Griesemer's two criteria. Firstly, such an emergent will maintain its emergence identity across the differing conceptualisations. Secondly, such an emergent is adaptable to different viewpoints as it can be considered as belonging to two different conceptualisations of emergence, each represented by the path from the root to the leaf of the multi-tiered typology. For example, consider the phenomenon of social capital which arises through social interaction (Putnam 1995) and so a member of the *//Product_of_complex_system/Macro_patterns-structure|processes/Non-linear_dynamics* type/subtype. As social capital cannot be simply reduced to the capabilities of individuals in isolation, it may also be viewed as being a member of the *//Ontological_novelty/Macro_property/Irreducibility/Weak* type/subtype. Thus, social capital can be used as a boundary object to facilitate comparing and contrasting of differing perspectives on emergence. The fact that potentially differing key characteristics can be inferred from the multi-tiered typology – for example weakly emergent can be inferred from the latter – is an added bonus.

This ability to identify conceptualisation spanning boundary objects is not found in most of the other typologies examined in Chapter 2 as all except Stephan (1992), Silberstein (2002) and Bar-Yam's (2004) are concerned with a single conceptualisation. Bar-Yam is arguably a classification typology which allocated objects – emergents – into unique types. As such, it cannot aid identification of interdisciplinary discourse boundary spanning emergents. However, both Stephan and Silberstein's typologies do have the potential to achieve this.

Consideration of alternatives and relation to other work

A non-typology approach could have been proposed, perhaps based on a collection of different analytical tools each designed to further understanding of a particular point. However, such a more eclectic set of tools, while arguably fitting with the pragmatic strategy of this research, would not have the benefit of the global coherence that the typology provides. Given that one of the main drivers for this research is to utilise the existing extensive discourse on emergence to try to offer a resolution to some of the conflicts and confusion, I strongly argue that global coherence is critical to the analytical task. Without this, we will not be able to profitably analyse the concept of emergence across all its forms. Additionally, as discussed above, the parsimonious nature of typologies offers a significant shortcut to describing conceptualisations of emergence.

In proposing a typology to try to improve understanding of emergence, I build on the likes of Stephan (1992), Bedau (1997), Jones (2002), Silberstein (2002), Bar-Yam (2004), Fromm (2005), Ellis (2006). Drawing on the analysis of Chapter 2, Table 2-4, p82, the nearest typology is perhaps that of Silberstein's (2002) which like the multi-tiered typology consists of top level groups and subgroups which are based on conceptualisations of emergence. Stephan's typology also concerns conceptualisations but on a single level. The types in other typologies of Table 2-4 are based on either generating conditions or irreducibility in the case Bedau (1997). Stephan and Silberstein's conceptualisations are purely philosophical based – ontological or epistemological. While there is sound reason for doing this from a purely philosophical perspective, as I have argued in this chapter and the previous, there is significant advantage to be gained from explicitly embracing the different conceptual dimensions relating to the proposed broad conceptualisation of emergence.

As I have argued throughout this chapter, the multi-tiered typology which I propose here is significantly different from the preceding typologies. The major innovation is basing it on idealised types[53] rather unique classification systems of emergence or emergents which the others apart from Stephan and Silberstein's all purport to be. However, I would argue, these do not really capture overlaps in conceptualisations. For example, each type or subtype has unique key characteristics. The advantage of the multi-tiered typology is that it has overlaps,

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[53] Note: Bar-Yam's typology is idealised in that it is mathematical. However, it still attempts to uniquely classify the mathematical types.

providing key areas of intersection which allow comparison and analysis of the structure of the various conceptualisations. Thus, the multi-tiered typology supports forms of comparison that Silberstein's does not. In the language of Doty and Glick (1994), the multi-tiered typology supports analysis because in is based on a set of domain variables – the key characteristics – which are combined in different ways to produce the idealised types. It is this which gives it its power to support 'higher-level' analysis. The multi-tiered typology therefore borrows significantly from Doty and Glick's work on the use of idealised typologies within organisational science. I strongly argue that this innovation is required given the apparently fuzzy nature of emergence. As I have argued, unique classification typologies simply would not be able to capture the extent of conceptual detail across the multiple conceptualisations and they would therefore not expose the interesting cases – the extremes and conflicts – from which we might learn.

In summary, in this section, the multi-tiered typology presented in section 5.1 has been analysed to assess its capabilities and limitations followed by its advantages. This led to the conclusion that the typology plausibly spans the emergence domain, is locally consistent and globally coherent and is conceptually founded. However, as the assessment of the capabilities illustrates that there is an underlying dependency on the extensive review of emergence presented in Chapter 2, the typology should be separately tested to assess its fitness for purpose – whether it can support communication and analytical discussion of emergence within an interdisciplinary context. The multi-tiered typology's ability to support analytical discourse led to three important advantages being identified – it provides: (i) an elaboration of the broad conceptualisation of emergence; (ii) a parsimonious framework for developing and conveying shared meaning of emergence within an interdisciplinary context; and (iii) a means of identifying boundary objects and their characteristic. These, I would argue, mean that as well as providing a categorisation of idealised types of emergence, the multi-tiered typology both helps clarify what emergence is and how understanding might be improved. Having completed the task of this chapter, the next section summarises the chapter developments, identifying the next stage in the research process.

5.3 Summary and implications

In this chapter the problem of developing a coherent elaboration of the broad conceptualisation of emergence that can focus and facilitate analytical interdisciplinary discourse on emergence has been addressed. This was achieved through the proposal of a new multi-tiered typology of emergence, based on the three general approaches to emergence and their subtypes and key characteristics which were identified in Chapter 2. The purpose of the typology is to support analytical interdisciplinary discourse and it thus forms a tool for improving understanding of emergence. How the typology might support communication, generalisation, prediction and extrapolation regarding emergence and real-world emergents was briefly illustrated.

Analysis of the capabilities and limitations led to the conclusion that the multi-tiered typology plausibly spans the emergence domain, is locally consistent and globally coherent, and is conceptually grounded – the key criteria required for it to support analytical interdisciplinary discourse regarding emergence and emergents. However, as there is an underlying dependency on the extensive review of emergence presented in Chapter 2, the typology should be separately tested to assess its fitness for purpose – whether it can support communication and analytical discussion of emergence within an interdisciplinary context. The proposed typology's ability to support analytical discourse led to three important advantages being identified – it provides: (i) an elaboration of the broad conceptualisation and thus provides an improved description of what is meant by emergence; (ii) a parsimonious framework for developing shared meaning of emergence within an interdisciplinary context; and (iii) a means of identifying interdisciplinary boundary objects and their characteristics – a key method in interdisciplinary problem solving. These, I would argue, mean that as well as providing a classification of types of emergence, the proposed typology offers clarification regarding what emergence is and how understanding might be improved. The proposed typology, therefore, further addresses *SQ-E– what is emergence*?

Thus, the multi-tiered typology offers a potentially valuable tool for improving understanding of emergence. Before discussing the next step, it should be noted that, as the multi-tiered typology draws heavily on the extensive literature review and the broad conceptualisation, it should be further tested. This issue will be returned to in Chapter 7. Further, there is still ambiguity regarding what is precisely meant by irreducibility and predictability as each of the conceptualisations corresponding to differing types/subtypes may fail to make clear what is meant by these terms or may use them differently from other conceptualisations. This too will be further considered in Chapter 6 and Chapter 7. Having established the broad conceptualisation and its elaboration, the next focus is how to aid understanding of real-world emergent phenomena.

Chapter 6 Understanding emergents

Attention is now turned to how understanding of real-world emergent phenomena might be improved. While the broad conceptualisation and multi-tiered typology provide insight into the nature of emergence and why at least some of the conflicts and misunderstandings surrounding emergence arise, they do not contribute directly to improved understanding of real-world emergent phenomena. Rather, they provide a conceptual framework which will allow us to explore such emergents by indicating (i) the type of information and understanding about it which we might reasonably expect to develop and (ii) how we might reasonably generalise and extrapolate given partial information. For example, as discussed in Chapter 5, section 5.1, the multi-tiered typology can be used to communicate why a participant considers a given phenomenon to be emergent, suggest where other similar emergents might be found and explore meaningful relations between key characteristics. Likewise, by considering different conceptualisations of emergence, the multi-tiered typology might also allow us to identify potential causes of an emergent through the *//Product_of_complex_system* type or characterise its potential behaviour through the *//Ontological_novelty/Macro_entity|rules/Macro_entity_causal_power* and *//Ontological_novelty/Macro_entity|rules/Downward_causation* subtypes. Not unsurprisingly, given that emergents by their very nature are difficult to fully understand, as discussed in Chapter 2, subsection 2.4.4 practical issues still exist with regard to understanding emergents. Not least is the issue of clarifying exactly what is the emergent under investigation. Further, key characteristics such as degree of irreducibility and unpredictability are still open to multiple interpretations. Understanding an emergent – description of the emergent, its causes and its behaviour – requires further elucidation. This chapter is, therefore, concerned with addressing *SO3 – development of a tool for generating an explanatory description of real-world emergents that can be used to (i) establish whether a real-world phenomenon is emergent; (ii) clarify exactly what the 'is emergent' relation is; and (iii) describe the full range of core and key characteristics relating to the instantiation, generation and behaviour of an emergent.*

The approach adopted is to develop an explanatory framework – the third conceptual proposal – which facilitates generation of neutral but conceptually-relevant description of an emergent, its causes and behaviour, thus offering an explanation of the emergent. 'Neutral but conceptually-relevant' means that the descriptions capture features and characteristics relating to different conceptualisations without requiring any particular conceptualisation of emergence to be adopted. The emphasis is therefore on the study of real-world phenomena rather than simply on the conceptualisations of emergence. The framework consists of four steps. Step 1 identifies the extent and complexities of the emergence system and the emergence relation under consideration. Steps 2-4 elaborate the key characteristics – meta-relational, generative and causal powers – considering both ontological and epistemological causes. Using this framework, it will be argued that improved explanations of emergents can be developed. However, the intrinsic complexity of many systems in which emergents arise, coupled with our current levels of understanding, may still limit the extent of the explanation. The explanatory framework, I will argue, has three important advantages over other approaches in the quest to improve understanding of emergence in all its forms. Firstly, the descriptions facilitate analytical discourse regarding emergence. Secondly, as I will contend that the descriptions are grounded in real-world phenomena rather than particular conceptualisations of emergence, they can be used to assess the broad conceptualisation and multi-tiered typology. Finally, by capturing the emergence system, the explanatory framework captures the complexities of physical and epistemological causation, providing a clear advantage over more traditional approaches which often focus on physical determinism. Thus, the explanatory framework addresses *SQ-RW – how might understanding of real-world emergent phenomena be improved?*

The chapter proceeds as follows. First, in section 6.1, the explanatory framework is presented. Its capabilities and limitations followed by its advantages over other approaches are then discussed in section 6.2. The chapter concludes, in section 6.3, by summarising the chapter developments and identifying the next stage in the research process.

6.1 A framework for explaining emergents

Having identified key requirements to improve explanation of emergents, this section presents a 'neutral' but conceptually-relevant framework for describing emergents, their causation and behaviour. As discussed in Chapter 3, subsection 3.2.2(c), the explanatory framework, captured in Figure 6-1 below, is based on the exploration of emergent phenomena from an emergence systems context. It is designed to gather information that will enable 'neutral' but emergence-relevant description of the emergence system and key characteristics which relate to the instantiation, causes and behaviour an emergent.

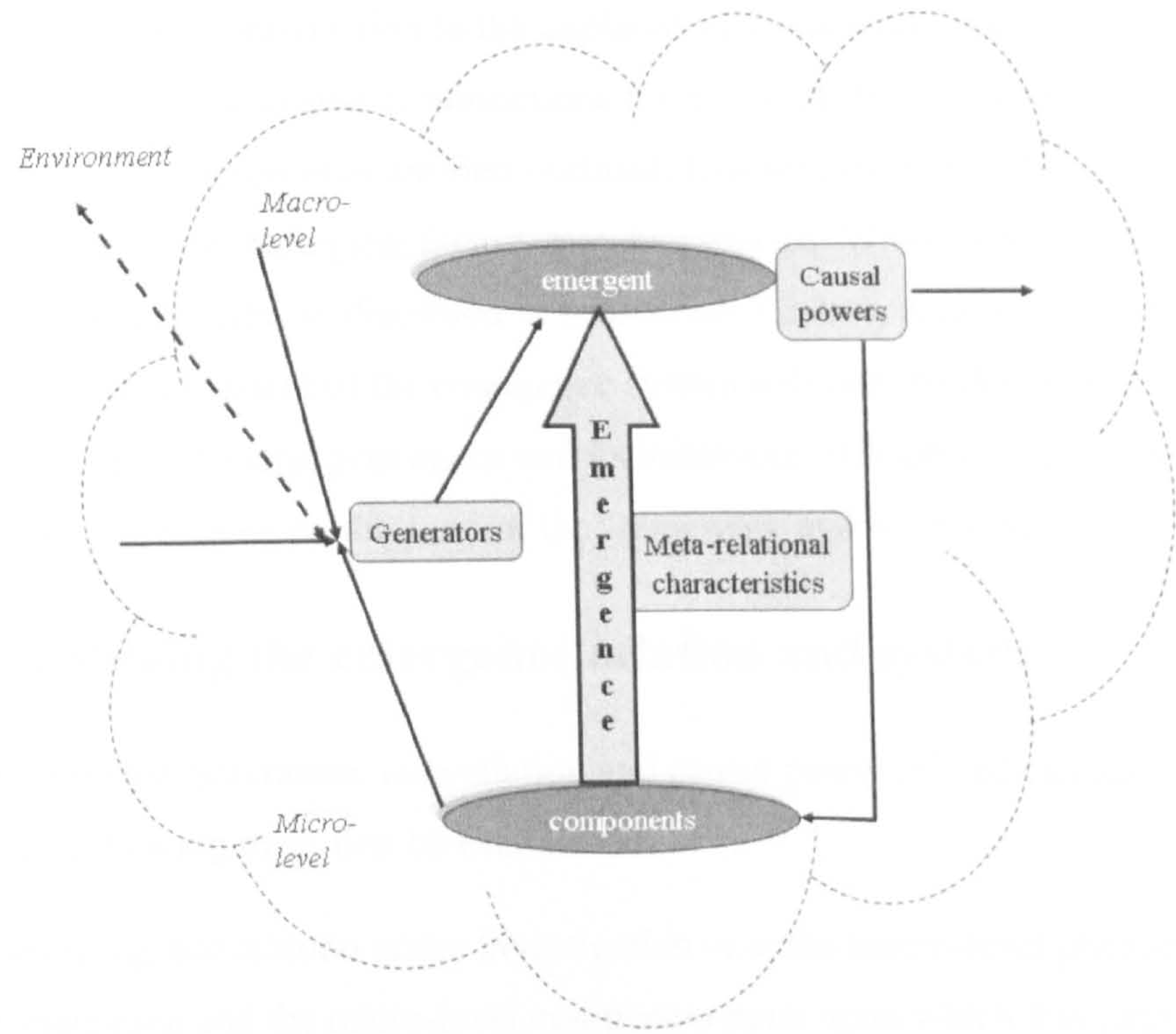

Figure 6-1: Overview of the explanatory framework and emergence system

Figure 6-1 above captures the four stages of the framework. The first stage, represented by the diagram as a whole, establishes the extent of the causal system under investigation and identifies exactly what emergence relation – the micro-level components and the related macro-level emergent – is being investigated. The cloud indicates that these components and the emergent phenomena which they give rise to are typically set within an open multi-levelled system, where they interact with non-linear dynamics. Importantly, this emergence system consists of ontological and epistemological factors. The remaining three stages represented in Figure 6-1 by the rectangular boxes –*Meta-relational characteristics, Generators,* and *Causal powers* – are concerned with describing the instantiation, causation and behaviour of the emergent. The position of the boxes illustrates how these facets form a critical, intrinsic part of the emergence system itself and therefore cannot reasonably be considered in isolation. In stages 2-4, the various key characteristics identified in Chapter 2, subsection 2.4.3 which relate to the instantiation, generation and causal powers of emergents, and how their perception might be influenced by epistemological factors are considered as opposed to adopting a particular conceptual approach to emergence and hence subset of key characteristics. Thus, the framework should aid development of 'neutral' but emergence-relevant description of emergents, theirs causes and behaviour.

Having provided a brief introduction to the explanatory framework, this section proceeds as follows. Stages 1-4 are described in subsections 6.1.1 – 6.1.4. In each subsection, the key subcomponents of the description are first outlined, followed by a brief discussion of how relevant causal and epistemological factors may be assessed. While these stages are by necessity presented linearly, as discussed in subsection 3.2.2(c), iteration will be fundamental as the full extent of the emergence system will only be drawn out through consideration of how the emergent arises and its behaviour. (Chapter 3, subsection 3.2.2(c) provides a fuller discussion on the form of the framework and its rationale.)

6.1.1 Establishing the emergence relation and system

Before exploring the generation, instantiation and causal power related characteristics of an emergent, the following must first be established:

(i) The emergence relation under investigation –i.e. the macro-level phenomenon under investigation and the micro-level component parts upon which it is physically determined but not manifest in the micro-level parts in isolation.

(ii) The extent and components of the 'causal system' in which the emergent occurs

This is achieved by iteratively considering the following questions

(i) What are the possible putative emergents?

(ii) What are their physical components?

(iii) How might these macro- and micro-level phenomena be related

  a. Synchronically?

  b. Diachronically?

(iv) What are the key organisational features of the system in which the emergence arises? The following should be considered:

  a. Multiple-layers

  b. Heterogeneity

  c. Subjectivity

(v) How does epistemology affect perception of the emergent:

  a. Scope?

  b. Resolution?

  c. Observation?

It is highly recommended that some form of visualisation technique such as rich pictures or concept mapping be used in the iteration process so that a cohesive representation of the emergence system may be built.

6.1.2 Meta-relational exploration

The relationship between macro-level properties and their micro-level constituent parts is at the heart of the concept of emergence. The meta-relational component of the framework (stage 2) explores the key characteristics of this relationship – i.e. the nature of the relation between the constituent micro-level components and the macro-level emergent. Stage 2 then consists of examining the emergent identified in stage 1 to establish:

(i) the form of each of the specified meta-relational characteristic – surprise, predictability from its constituent parts and the degree of (ir)reducibility of its explanation to its component parts;

(ii) how epistemological factors – scope and resolution – affect perception of the form of each meta-relational characteristic.

Table 6-1 summarises the meta-relational properties, their forms and epistemological factors that are considered within stage 2 of the framework.

Meta-relational characteristics			**Description**	**Examples & Comments**
Surprise			An indication of our lack of experience	May be loosely indicative of emergence
Predictability of emergent	*Classification of characteristic*	*Readily predictable*	The emergent is deterministic and readily predictable from knowledge of its component parts alone	Planned functionality of a machine
		In principle	Predictable in theory only due to non-linear interactions	Economic equilibrium
		Statistical	The emergent is non-deterministic , but predictable through statistical analysis	Quantum phenomena
		Unpredictable	The emergent is not predictable even in principle	Quantum mechanics?

Meta-relational characteristics			Description	Examples & Comments
	Epistemological Analysis	*Scope*	Difficulties in predictability arise from the scope of analysis. Using a wider scope, the predictability would be different.	Epistemic influence; e.g. new functionality of a machine is unpredictable because the wider context in which it could be applied has not been examined
	Epistemological Analysis	*Resolution*	Degree of predictability depends on theory and scale of analysis	Epistemic influence; e.g. chemical properties were unpredictable until quantum mechanics was used
Reducibility of explanation	*Classification of characteristic*	*Sum*	Explainable through the linear, cumulative properties of components	The weight of a crate of apples[54] is explained by summing the weight of each apple.
Reducibility of explanation	*Classification of characteristic*	*(Complex) Product*	Explainable through the properties of components and their interactions. Particularly complex products are thus noted.	Functionality of a machine
Reducibility of explanation	*Classification of characteristic*	*Irreducible*	Requires macro-level explanation	Possibly the mind
Reducibility of explanation	*Epistemological analysis*	*Scope*	Changing scope increases the reducibility of explanation	Smell of ammonia
Reducibility of explanation	*Epistemological analysis*	*Resolution*	Degree of explainability depends on theory and scale of analysis	Thermodynamic properties

Table 6-1: Meta-relational characteristics examined within the explanatory framework

[54] It is not claimed that this is an example of emergence.

As Table 6-1 above illustrates, analysis of the phenomenological key characteristic of surprise is included, despite the fact that it is not objective - see Chapter 2, subsection 2.3.2. It is included because consideration of whether an emergent is surprising reveals both current levels of understanding and philosophical perspectives. Unpredictability as discussed in Chapter 2, subsection 2.4.3 offers a more objective, but equally epistemological assessment of the emergence relation. While the behaviour or existence of a property or entity is arguably either predictable or unpredictable, this does little to further understanding of why it occurs or on what assumptions the assessment of predictability is based. Thus, rather than simply evaluating the meta-relational property as unpredictable or not, as Table 6-1 captures, the 'type' of predictability – *readily predictable, reducible in principle, statistical and unpredictable* – is examined to help assess its cause.

Irreducibility is described in terms *sum, (complex) product* and *irreducibility.* The term complex is used to describe instances where the interactions are particularly complex. As Table 6-1 illustrates, the terms weak and strong have been avoided as they have various different uses throughout the literature; rather the specific causes of the (ir)reducibility is analysed. This principle is applied throughout the explanatory framework.

By examining these meta-relational properties, where possible, at different scope and resolutions, insight into the relationship of the emergent to its components and the role our perception and theory play in our understanding of the emergent will be gained.

Finally, while not shown for clarity, it should be noted that in the meta-relational exploration framework above and in those of the following stages, there is always the option of 'other' if the characteristics of the emergent do not fit with those specifically detailed. Identification of 'other' categories would lead to a refinement of the framework in line with the pragmatic strategy of this research.

6.1.3 Generators exploration

Stage 3 of the explanatory framework is concerned with gathering data pertaining to the process that gives rise to phenomenon – that is the generation (cause) of the macro-level phenomenon from individual micro-level components and not its conceptualisation as emergent. Stage 3 then consists of examining the emergence system and the emergent identified in stage 1 to establish:

(i) what types of constraints – components and their relations, macro-level rules which restrict component behaviour or 'relational' constraints between phenomena – are causal generators of the emergent;

(ii) how these constraints arose – through self-organisation, manufacture and/or design, prior emergence or inherent subjectivity;

(iii) what type of epistemological generators – observation and reasoning – appear to play a causal role;

(iv) how epistemological factors – scope and resolution – affect perception of the form of generator characteristics.

Table 6-2 below summarises the generator characteristics, their forms and epistemological factors that are considered within stage 3 of the framework.

Generators		**Description**	**Examples & Comments**
Constraints	*Component*	Constraints in component behaviour gives rise to emergent properties	Bénard Cells, Life, Bird flocking patterns
	Macro	The behaviour of the component parts is constrained by macro-level rules, which in turn give rise to new collective properties	Bar-Yam's examples such as collective trade-offs, social rules which constrain the behaviour giving rise to marriage
	Relational	The constraint is between 'compound objects' rather than micro-level components	Bar-Yam's lock and key
Construction of macro-level characteristics	*Self-organisation*	The emergent is in part at least the result of self-organisation of its component parts	Bénard Cells, Life, Bird flocking patterns
	Manufacture	The emergent was deliberately constructed from its component parts	Functionality of a machine
	Design	The emergent was planned.	Planned functionality of a machine
	Prior emergence	The behaviour of the component parts is constrained by previous emergents. The previous emergence could macro-level	Emergence of organs depends on prior emergence of cells and reproductive

Generators		Description	Examples & Comments
		rules or entities.	processes
	Subjectivity	The ability to distinguish between parts of the system gives rise to new macro-level properties	Conceptual development, biological functionality
Epistemological generators	*Observation*	Observation contributes to the generation of the emergent	Thermodynamic temperature
	Reasoning	Reasoning gives rise to the generation of the emergent	The concept of thermodynamic entropy
Epistemological influences	*Scope*	Different scope change perception of generators	
	Resolution	Different scale and theoretical context changes perception of generators	

Table 6-2: Generators of emergence examined within the explanatory framework

The 'Constraints' identified in the first three rows of Table 6-2 above consider the physical causes of the properties. As discussed in Chapter 2, subsection 2.4.3 and section 2.4.4, these might be expected to include the constraints identified by Bar-Yam (2004) - component interactions, the interaction between macro (or system) rules and the micro-components and 'relational' constraints between compound objects. The term 'relational' constraint here captures what Bar-Yam means by environmental constraint. However, as the explanatory framework employs a much wider emergence system, the environmental object which gives rise to the constraint is now part of the system – hence the change of terminology[55]. For example, both ammonia and nasal receptors are considered within the emergence system and environmental constraint really refers to the constraint between these two prior emergents, the term environmental is no longer really appropriate.

The 'cause' of the generation – its construction – is included in the investigation for three reasons. Firstly, it helps view the role that self-organisation plays – a key complex systems

[55] The term 'relational constraint' is used to capture a constraint between non-micro-level parts of the system and is therefore distinct from constraints that are between micro-level components. Clearly these micro-level constraints are also relational in nature.

perspective on emergence – see Chapter 2, subsection 2.3.3. Secondly, by considering the role of manufacture and design it offers insight into whether emergents may be engineered. Thirdly, the consideration of the role of prior emergence and subjectivity of the system – the idea that differentiation within the system lets one part use another to give rise to emergence – helps to identify where system complexity might both generate emergence but hinder its understanding. Subjectivity in this sense should not be taken to mean perceptual or conceptual influences of an external observer. Rather this subjectivity relates to the components within the emergence system itself.

The epistemological generators – observation and reasoning resolution – are designed to cover the role that our observations and conceptualisations play in the generation of an emergent. Observation considers whether the emergent would exist without our observation and reasoning captures the type of causal power discussed in section 2.4.4, where conceptual powers can lead to potentially ontological emergence. Clearly, where humans are components of the emergence system then observation may equate to the subjectivity discussed in the preceding paragraph.

The epistemological influence – scope and resolution – are included to ensure that the role that our perception and theory plays in our understanding of the generation of the emergent phenomenon is considered. Scope investigates whether extending the scope of the emergence system under observation changes the view of its generators. Resolution considers the role that our conceptualisation – our power of reason – plays. Scope and resolution are not expected to have real causal power; rather they modify how we perceive the generators. Additionally, interpretation of these components may vary greatly depending on philosophical perspective. For example, does the smell of ammonia exist without someone being there to perceive it?

Using Table 6-2 to analyse the constraints, construction, epistemological generators and epistemological influences should help generate insight into the origin of an emergent.

6.1.4 Causal power exploration

Stage 4, the causal power component of the explanatory framework is concerned with exploring how the emergent affects macro-level behaviour and that of its micro-level constituent parts. Consideration of the macro-level causal powers is key because, as described in Chapter 2, subsection 2.3.1, it is observation of apparent novel macro-level interactions which often stimulates interested in a phenomenon as emergent. Stage 4 then consists of examining the emergence system and emergent identified in stage 1 to establish:

(i) the form of each causal power characteristics – macro-level causal power surprise and downward causation;

(ii) how epistemological factors – scope and resolution – affect perception of each form of meta-relational characteristic.

Table 6-3 below summarises the causal power characteristics, their forms and epistemological factors that are considered within stage 4 of the framework.

Causal power		**Type**	**Description**	**Examples & comments**
Macro-level	*Classification of characteristic*	*Sum*	The emergent apparently affects other macro-level components, but the action is simply reducible to that of the parts upon which the other macro-level components and the emergent are physically determined.	Pressure
		(Complex) Product	The emergent affects other macro-level components, but the action is reducible in principle – i.e. non-simply reducible – to the properties and behaviour of the parts upon which the other macro-level components and the emergent are physically determined. Particularly complex products are thus noted.	Apparent global rules in Conway's game of life Chemical interactions are reducible in theory to quantum dynamics
		Irreducible	The emergent affects other macro-level components, but the action is not reducible even in principle to the parts upon which they are physically determined.	Silberstein's (2002) nomological emergence
	Epistemological Analysis	*Scope*	Observation with a different scope reduces the 'strength' of macro-level causal power	

Causal power		Type	Description	Examples & comments
		Resolution	Using a different theory, the 'strength' of macro-level causal power could be reduced	
Downward causation	*Classification of characteristic*	*Attractor reducible*	The macro-level emergents arise out of attractor dynamics of the system. This capture over time of system dynamics into attractor basins constrains micro-level behaviour	property market bubble
		Constraining	The macro-level emergents are constraining conditions for the activity of micro-levels	Sperry's (1987) view that the mind governs the physical components of the brain without directly interacting with them.
		Irreducible	The emergent affects its component parts, but the action is not reducible to the parts upon which it is physically determined	Captures the strong ontological emergence of the mind
	Epistemological Analysis	*Scope*	Observation with a different scope reduces the 'strength' of downward causation	
		Resolution	Using a different theory could change the 'strength' of downward causation	

Table 6-3: Causal power characteristics examined within the explanatory framework

As Table 6-3 details, macro-level causal power is assessed in terms of degree of irreducibility – sum, (complex) product and irreducible – as is the micro-macro relation in stage 2 of the explanatory framework. Epistemological factors are also highly likely to influence the conceptualisation of the type of macro-level causal powers. For example, the type cannot be reasonably analysed by considering the emergent and its components alone. The macro-level entities which it acts upon and their component parts must also be considered before a reasonable conclusion as to reducibility or not may be made – thus scope will be critical to analysis. Further, is to be expected that, due to complexity and current knowledge, in some cases this might be beyond resolution at present or may simply lead to a wrong conclusion.

Analysing downward causation might be expected to be equally difficult. Here the exploration is based on Emmeche et al's (2000) types of downward causation – see Chapter 2, subsection 2.3.1 – which is drawn to a large extent from complex system dynamics. However, as Table 6-3 illustrates the terminology is changed as the terms weak and strong have again been avoided in order to improve analysis of the underlying causal structure. Thus, the degree of irreducibility is analysed in terms of 'attractor reducible', constraining and irreducible, which are at the basis of Emmeche et al's types. Again, epistemological influences on the perceived downward causation are also included in the exploration.

Using Table 6-3 to analyses the causal powers of emergents will: (i) enable explanation of the role of the emergent in explaining and determining macro and micro-level behaviour and (ii) expose the ontological, epistemological and complexity facets that contribute to this. However, it should be noted that in many cases the analysis will be provisional due to the level of current understanding.

In summary, in this section an explanatory framework for developing 'neutral' but conceptually-relevant descriptions of emergent phenomena, their causes and behaviour has been proposed. Key to the framework is identifying: exactly what constitutes the emergence relation under consideration; its potential causal influences; and the effect of different epistemological perspectives on the description. The framework provides overall advice and guidelines for what a profitable explanation of emergents might reasonably entail. How the required information is gathered is left unspecified as this depends on the particular phenomenon under consideration. The next section examines in detail the capabilities, limitations and advantages of the explanatory framework.

6.2 Discussion of the explanatory framework

Having proposed an explanatory framework which is designed to facilitate 'neutral' but conceptually-relevant description of an emergent and its causes and behaviour, this section analyses the framework. First, in section 6.2.1, its capabilities and limitations are analysed to assess whether the framework is fit for purpose. This is followed, in subsection 6.2.2, by discussion of the advantages of the explanatory framework in relation to other approaches and its implications.

6.2.1 Capabilities and limitations of the explanatory framework

The rationale for developing an explanatory framework is to facilitate improved understanding (explanation) of emergents. This, it was argued, could be achieved if the description addresses at least some of the problem areas associated with explaining emergents and facilitate further extrapolation regarding emergents using the multi-tiered typology. To achieve this, it was argued in Chapter 3, section 3.2.3(c) that the explanatory framework should satisfy the following three criteria: (i) develop 'neutral' but conceptually-relevant descriptions of (ii) the instantiation, causation and behaviour of the emergent (iii) paying particular attention to capturing the causal environment, how different epistemological factors might affect the description, and what is meant by the key characteristics it identifies. This subsection considers, in turn, the extent to which the explanatory framework satisfies these three criteria, followed by potential limitations. The subsection then ends by summarising what might be concluded regarding the fitness of the explanatory framework and identifying what other steps are required to assess it.

The claim that the explanatory framework is conceptually-relevant, I argue, is plausible as it produces descriptions which consider the full range of all but one of the key characteristics identified from the extensive literature review of Chapter 2, section 2.3 and summarised in subsection 2.4.3. The exception is non-deducibility. However, I argue that non-deducibility is implicitly covered through consideration of the effect of resolution on the irreducibility of the micro-macro relation. For example, applying the explanatory framework to the emergence of thermodynamic temperature from the properties of constituent particles, the resulting description would describe the relation between temperature and the particles as reducible to the sum of the kinetic energy of the particles plus a conceptual translation that equates average kinetic energy with a micro-level idea of temperature – see Chapter 7, example 7.1(b). From this it may be inferred that thermodynamic temperature is deducible when this conceptual translation is applied but non-deducible otherwise.

Neutrality might reasonably be assumed if the framework can be shown to be independent of philosophical stance, specific conceptualisations of the emergence relation, and disciplinary language and perspectives. These three conditions are considered further. Firstly, as the framework makes no stipulation regarding the degree of irreducibility, rather examining the origins of the meta-relational and causal powers, I argue that it makes no presumptions regarding both reductionist and emergentist views. Further, as it also investigates both ontological and epistemological components, I argue, it is neutral to philosophical stance, at least within a non-vitalist framework. Secondly, the explanatory framework is independent of specific conceptualisation of emergence as it covers the full range and forms of the characteristics associated with the emergence relation. Consideration of the forms of the key characteristics is important as it accommodates the various conceptualisations which have differing opinions regarding what is meant by, for example, irreducible or downward causation. Further, the emergence systems approach ensures that both logical and dynamical interpretations of the emergence relation may be considered as required. Thirdly, the description of the key characteristics and their various forms in Table 6-1 - Table 6-3 of stages 2-4 attempts to make explicit how such terms should be interpreted. By making explicit what is meant by these key characteristics, this should, I would argue, help minimise language and other disciplinary perspectives in stages 2-4. This is more difficult to achieve in stage 1, hence the advice to consider how other disciplines might interpret the emergence system. Iteration of the stages should also help minimise this. Thus, I argue, the framework makes a plausible effort at being neutral to disciplinary language and perspectives.

The ability to capture the instantiation (what the emergent is), how it is generated (its causation) and how it behaves (its causal power) is critical to whether the explanatory framework can be said to offer an explanation of an emergent. A full explanation is a significant task. However, as this thesis is concerned with profitable and not ultimate explanations, I argue that if the explanatory framework can be shown to make a reasonable attempt at covering the range of key characteristics associated with the instantiation, causation and behaviour of an emergent, which were extracted from the literature review in Chapter 2, subsection 2.4.3, then it might be argued that it provides a plausible approach to describing emergents. It has already been argued in the previous section that the framework considers the range of key characteristics of emergence, which were grouped into those associated with instantiation, generation and behaviour in Chapter 2, subsection 2.4.3. The extent to which this consideration might actually provide information – i.e. the actual degree of coverage of the key characteristics, and hence the instantiation, causation and behaviour of an emergent – I argue, depends on the ability of the framework to capture the full causal environment of the emergent. This is considered next.

Capturing the full range of the causal environment, as section 3.2.3(c) argues, is vital if the description developed is to offer a coherent explanation of the emergent. Without this, the meaning of the characteristics is open to variable interpretation. The explanatory framework approaches this in two ways. Firstly, the Stage 1 exploration of the emergence system attempts to identify the physical and epistemological system in which the emergent arises and its potential causal influences. It achieves this by specifically considering multiple-levels, heterogeneity and subjectivity within the system and how scope, resolution and perception might affect identification of the system, all within a dynamical systems context. It, thus, utilises the key contributing factors to emergents synthesised from the literature review in Chapter 2, subsection 2.4.3. The inclusion of scope is particularly relevant as it encourages consideration of wider causal influences than might not at first be thought relevant. Secondly, iterations of the stages, especially after the examination of the key characteristics associated with generation (causes) of the emergent in Stage 3, enables the causal environment to be refined in light of experience. I thus argue, the explanatory framework makes a reasonable effort to capture the causal environment.

The inclusion of epistemological factors such as scope, resolution and perception in all four stages, illustrates how the explanatory framework attempts to capture how varying epistemological influences affects the explanation of an emergent. These factors are identified in Chapter 2, subsection 2.4.3 and section 2.4.4 as the key epistemological influences on our understanding of emergence and emergents. Without such epistemological considerations, the explanations generated will be specific to a particular perception, leading to incoherence and confusion when we try to generalise.

The meaning of the key characteristics of emergents is clarified by breaking down predictability and irreducibility into differing forms. For example, rather than simply stating that the small world structure of the World Wide Web was unpredictable, using the explanatory framework it is characterised as *'Predictable in theory only, due to non-linear interactions'* – see Chapter 7, example 7.1(e). This provides much more information than simply stating it is unpredictable as it begins to hint at an explanation of the unpredictability.

Two limitations relating to neutrality and conceptual-relevance can be identified. Firstly, the review process of Chapter 2 may have failed to identify key characteristics. As argued in Chapter 5, subsection 5.2.1, the extensive review technique, should give confidence through the extent of coverage. Again, I would argue that this best effort approach is sufficient for purpose as the pragmatic ethos adopted in this research embraces refinement of proposals in light of experience. What is important is that there is reasonable conceptual and empirical data to support the range of key characteristics. The extensive review provides this. Secondly, while the explanatory framework specifies the key characteristics to be considered, this does not necessarily imply that we will be able to determine the key characteristics. For example, the degree of irreducibility of the mind to the physical brain is still unknown.

Three limitations to the explanatory framework's ability to capture the causal environment can be identified. Firstly, given the difficulties in understanding emergent phenomena, actually identifying the full emergence system and its causal structure may prove difficult if not infeasible due to current levels of understanding. Secondly, this is further restricted by the non-linear nature of the emergence system where information may be lost. For example, as we do not currently know how the mind arises from the brain or indeed how it first evolved, it will be impossible to establish undisputed generators of the mind. However, by considering the different types of generators and how they might be related, possible generators can at least be exposed and discussed. As ever, the caveat that future development of knowledge may change the status of key characteristics such as irreducibility or predictability must be borne in mind. However, it should be noted that some of the generating information may be permanently lost. Further, as epistemological or psychological factors may apparently affect emergence in social systems, this may make identification of causes infeasible in some cases. Thirdly, since by necessity, any investigation considers a subset of the real world, the radical openness often associated with complex systems cannot be closed (Chu et al. 2003).

In conclusion, the preceding assessment of the capabilities and limitations of the explanatory framework, I contend, illustrates that the explanatory framework makes best effort to describe an emergent, its causes and behaviour as neutrally but conceptually-relevant as possible. The biggest potential issue in achieving its objectives is the feasibility of use – whether the desired information can actually be collected and whether a coherent description can thus be developed. Thus, the real test of usefulness of the explanatory framework will be whether it can be used to develop coherent descriptions of emergents which can then be used in analytical discourse to improve understanding of emergence.

6.2.2 The advantages and implications of the explanatory framework

As argued in the preceding subsection, the explanatory framework presented in section 6.1 provides a plausible method of generating an explanation of an emergent in the form of a 'neutral' but conceptually-relevant description of its instantiation, causation and behaviour. In addition, the explanatory framework provides three important advantages in the quest to improve understanding of emergence in all its forms: the descriptions may be used to support analytical discourse regarding emergence, complementing the broad conceptualisation and multi-tiered typology; it may be used to assess the usefulness of the broad conceptualisation and multi-tiered typology; and finally, it captures the emergent base – ontological and epistemological – rather than simply the physical base which, I argue, improves explanation. Each advantage is discussed in turn below, followed by a comparison with other approaches.

A complementary aid to analytical discourse

The explanatory framework facilitates analytical discourse regarding emergents. It achieves this in two key ways, which are discussed below. Further, I argue, the manner in which it achieves this complements how the multi-tiered typology supports improved understanding of emergence. Thus, the explanatory framework is a key conceptual tool for supporting interdisciplinary discourse on emergence.

Firstly, the descriptions generated using the explanatory framework can be used with the aid of the multi-tiered typology to analyse and compare emergents. The three following examples are illustrative of how this may be achieved. (i) The multi-tiered typology can be used to group the descriptions, and hence the emergent phenomena, into idealised types. Where such phenomena can be shown to share other – non-type defining – characteristics then this allows extrapolations to be made regarding potential characteristics of newly matched emergent, where only partial information exists. (ii) Where the 'neutral' but conceptually-relevant descriptions can be assigned to more than one type/subtype within the multi-tiered typology then they may be used to explore whether there are hidden meaningful relationships between key characteristics of emergents. (iii) As the descriptions generated should cover all key characteristics, the matching of an emergent to different type/subtypes will enable comparison of how the emergent fits within the different conceptualisations. Further, as the description is developed independently of the multi-tiered typology, iterative consideration of the fit of these different conceptualisations and the description of an emergent, I suggest, should aid validity of the both the descriptions and the idealised types of emergence.

Secondly, the descriptions themselves may be examined for common trends and linkages – causal or behavioural – independent of the multi-tiered typology. For example, a group of these descriptions could be examined to assess if there is any empirical linkage between multi-level subjectivity in the emergence system and perceived irreducibility of the emergence relation. As the explanatory framework covers the key characteristics of emergence, this effectively allows an empirical phenomenon-based analysis of the key variables of the conceptual domain relating to emergence. The analysis is phenomenon-based in that it is based on 'neutral' observation and consideration of emergent phenomenon and not on particular conceptualisations of emergence.

The explanatory framework, I contend, therefore complements the broad conceptualisation and multi-tiered typology. This is principally because it allows real-world phenomenon-grounded, as opposed to conceptualisation-grounded, descriptions of emergents to be developed. As illustrated above, it thus provides conceptualisation-'independent' descriptions for use within the multi-tiered typology and facilitates complementary independent conceptual analysis. Importantly, it should be noted that the explanatory framework is not an alternative to the multi-tiered typology. The structure of the multi-tiered typology facilitates far more sophisticated conceptual analysis regarding emergence than the explanatory framework can. In particular, it encapsulates different disciplinary knowledge regarding emergence, something which is absent within the explanatory framework.

A tool for assessing the conceptual proposals

The framework may also be used to assess the broad conceptualisation and multi-tiered typology. This is possible because the descriptions it produces are separately grounded from the other two conceptual proposals. This is the case because while the broad conceptualisation, multi-tiered typology and the explanatory framework are all developed from synthesis of the extensive material within the literature review, the descriptions generated by the explanatory framework, I argue, are grounded by the real-world phenomena and not the review. This claim is justified because the explanatory framework has no conceptual structure save (i) what explanation entails – i.e. instantiation, causation and behaviour, (ii) it has a complex causal system and (iii) the key characteristics and their subtypes and qualifiers. The first is irrelevant to grounding interdependencies and as the second also includes a non-complex causal system as a trivial case, it is effectively causal structure neutral. The third element of conceptual structure – the key characteristics and their subtypes and epistemological qualifiers – does draw significantly on the review material. However, these are only introduced to ensure conceptual relevance and their subtypes draw on current scientific understanding on the different causes of these variations in degrees of the key characteristic and epistemological understanding of knowledge *per se*. Indeed, the conceptual structure associated with an individual key characteristic within the framework does not appear in either the broad conceptualisation of emergence or the multi-tiered typology. Thus, I contend, the framework is not built on any inference as to how these key characteristics are related or what the dimensions of the conceptual space are. Therefore, I further contend, the conceptual foundation of the descriptions generated by the explanatory framework is sufficiently distinct to enable their use in assessing the broad conceptualisation and multi-tiered typology. How this might be achieved is briefly discussed below.

In the case of the multi-tiered typology, the descriptions generated from the explanatory framework may be used to assess its capabilities. For example, if through the description, emergents may be grouped into one or more subtypes and if predicted characteristics are found to match ones from the descriptions then a reasonable assessment of the multi-tiered typology's ability to classify putative emergents and extrapolate characteristics – two of its key drivers – can be made. Additionally, independent application of the explanatory framework and analytical synthesis may provide corroboration of the multi-tiered typology's deductions and hence the multi-tiered typology's plausibility as an analytical tool.

Similarly, the plausibility of the broad conceptualisation of emergence may be assessed as the explanatory framework neutrally spans the dimensions of the emergence domain. For example, if it can be shown that an emergent can be coherently described with reference to ontological and epistemological causes and complexity, then this would support the plausibility of the broad conceptualisation of emergence of Chapter 4. This is a clear advantage over the other approaches in the literature which are either ontologically or epistemologically focussed or as in the case of the complex product approaches oblivious to many key characteristics.

Captures the emergence base as opposed to the physical base

The description of the emergence relation is based on the wider emergence system as opposed to supervenience or the physical relation between macro- and micro-level components. This, I argue, provides advantages over other approaches for two reasons.

Firstly, as discussed in section Chapter 2, section 2.4, emergence in many cases is not a simple relation between macro- and micro-levels. If a complex emergent is to be understood then the description should capture these complexities. Further, while a purely physical description may capture physical determination, as more recent understanding from complexity science reveals, relationships with other system and environmental objects – i.e. organisation – are vital to explanation, at least within a non-linear context. However, as discussed in section 2.4.4, the heterogeneous and multi-levelled nature may lead to the development of subjectivity, with its original physical causal structure lost in time. As we cannot retrieve this lost information, I would argue that we need to utilise concepts like subjectivity to adequately describe emergence. As in the examples discussed in section 2.4.4, multiple levels of explanation which "mix different levels of aggregation" (Silberstein 2002, p100) are often required. The framework achieves this by incorporating and extending the insights of the likes of Bar-Yam (2004) and Collier and Muller (1998) to examine system and environmental constraints within a multi-layered *and* subjective context.

Secondly, I would argue that consideration of epistemological causes provides a valuable conceptual tool. Given non-vitalism, epistemological causes must also be physically determined. But, as argued above, loss of information will make it effectively impossible to equate epistemological causes to physical ones. However, as we can analyse and theorise about epistemology – a fundamental stream within philosophy – we can at least leverage this to improve understanding of emergent phenomena. This distinction is particularly relevant as O'Connor (2005) argues that emergent properties are so described because of their causality – without consideration of epistemological causes within the emergence system, a very incomplete picture would be achieved.

Consideration of alternatives and relation to other work

Three different types of approach to the problem of improving understanding of emergents can be identified. Firstly, an explanatory model rather than a framework could have been attempted. However, as argued in Chapter 1 and further substantiated by the review of Chapter 2, the current state of understanding regarding emergence does not permit a single explanatory model to be developed. Clearly, there are many well documented explanatory models of individual examples of emergents – the ants model (Gordon 1999) mentioned in Chapter 1 or the Boids model (Reynolds 1987) being two good examples. Secondly, an approach based on a specific conceptualisation of emergence could have been used to try to improve understanding of emergents. The problem with the individual conceptualisations identified in the literature review is that apart from the product of complex systems based approaches, none of the conceptualisations are concerned with the causes of emergents; often they simply either leave it as a black box (Goldstein 1999) or simply attribute it to complexity. The disadvantage of simply adopting a product of complex systems based approach is that these, in general, fail to take into account either epistemological influences such as resolution or epistemological causes such observation. Thirdly, the multi-tiered typology might have, at first sight, appeared to offer a reasonable tool for improving understanding of emergents; indeed, as acknowledged in both Chapter 5 and 6.2.1, it does aid conceptual analysis of emergents. However, as discussed in the introduction to this chapter, it does not directly provide an explanation of a particular real-world emergent as it is a conceptual tool designed to enable comparison and extrapolation rather than description of a phenomenon and its causes and behaviour.

As the framework uses the key characteristics of emergence identified in the extensive literature review, it clearly builds on this substantial body of work. While having a complex emergence system as its base means it draws substantially from the product of complex system approaches of Chapter 2, subsection 2.3.3, the framework also draws on approaches such as (Bedau 1997, Collier and Muller 1998, Ellis 2006) who begin to bring complex systems perspectives to philosophical discourse on emergence. However, these approaches serve a different purpose, with Bedau's and Ellis's being typologies and Collier and Muller's being more of a conceptual discussion than a framework. It also draws heavily on Bar-Yam (2004) and Ryan (2006) in its analysis of types of constraints and epistemological influences.

The innovation of the explanatory framework proposed here is threefold. Firstly, it combines complex systems with ontological and epistemological consideration to improve explanation. While Bedau, Ellis, and Collier and Muller's do mix complexity with philosophical approaches, I contend that none of them considers the epistemological factors that I argued are highly relevant to explaining emergence. Secondly, the inclusion of subjectivity, as I argued above, is an important asset of the explanatory framework, and this attempts to incorporate Crutchfield (1994) and Shalizi's (2001) notion of emergence arising as a result of the information structure within a complex system. Finally, again as argued above, the explanatory framework facilitates phenomenon-grounded as opposed to conceptualisation-based explanatory descriptions of emergents. Thus, unlike the majority of investigatory approaches to emergence, it potentially offers the opportunity of synthesis of proto-theory from the data. It is thus akin to the social sciences grounded theory approach of Glaser and Strauss (1967) that seeks to build theory from qualitative data (Miles and Huberman 1994).

In this section, the explanatory framework presented in section 6.1 has been analysed to assess its capabilities and limitations followed by its advantages and its relation to other work. This led to the conclusion that the explanatory framework is a plausible tool for developing 'neutral' but conceptually-relevant descriptions of emergents, their causes and behaviour. However, given such phenomena are inherently difficult to explain, the usefulness of the tool depends on its practical implementation which should be separately assessed. The explanatory framework's ability to generate real-world phenomena-grounded descriptions led to three important advantages being identified: the descriptions may be used to support analytical discourse regarding emergence, complementing the broad conceptualisation and multi-tiered typology; it may be used to assess the usefulness of the broad conceptualisation and multi-tiered typology; and it captures the emergent base –

ontological and epistemological – rather than simply the physical base which, it was argued, improves its explanatory capacity. Having completed the task of this chapter, the next section summarises the chapter developments and identifies the next stage in the research.

6.3 Summary and implications

In this chapter the problem of improving understanding of emergents has been addressed. This was achieved through proposal of an explanatory framework for development of neutral but conceptually-relevant descriptions of emergents, their causation and behaviour. The core of the framework is based on identifying the extent and complexities of the emergence system – the emergence relation and its causal network – under consideration. Three further steps investigate the key characteristics – meta-relational, generators and causal powers – considering both ontological and epistemological causes. Analysis showed that the framework meets the key requirements for plausibility – that it (i) develops 'neutral' but conceptually-relevant descriptions of (ii) the instantiation, causation and behaviour of the emergent (iii) paying particular attention to capturing the causal environment, how different epistemological factors might affect the description, and what is meant by the key characteristics it identifies. However, the ability to gather the required data was identified as its biggest potential limitation. This suggests its usability should be practically assessed.

The explanatory framework provides three important advantages over other approaches in the quest to improve understanding of emergence in all its forms. Firstly, its neutral but conceptually-relevant approach means that the descriptions may be used to support analytical discourse regarding emergence. Secondly, this approach means that the descriptions generated are grounded in real-world phenomenon rather than particular conceptualisations of emergence. This grounding is significant as it allows the descriptions to be used to independently assess the usefulness of the other conceptual proposals of Part II. Thirdly, by exploring the emergence system – i.e. the full base of the emergence – the explanatory framework attempts to capture the complexities of physical and epistemological causation, providing a clear advantage of more traditional approaches which focus solely on physical determinism. Thus, the explanatory framework principally answers *SQ-RW – how might understanding of real-world emergent phenomena be improved?*

In the discussion of the framework, how it might be used (i) in combination with the other conceptual proposals to support analytical analysis and (ii) to assess the other conceptual proposals was briefly discussed. This and assessment of the usefulness of the explanatory framework itself are the subject of the next part of this thesis. Before proceeding to Part III, the developments and conclusions of Part II are briefly summarised next.

Part II – Summary and Conclusions

Part II of this thesis has been concerned with conceptual development to improve understanding of emergence. Three separate conceptual proposals were developed, each of which it is argued below forms a key role in the quest to improve understanding of emergence. Each of the conceptual proposals is summarised, followed by a brief discussion on how they complement each other in the task of improving understanding of emergence. This summary, and Part II of the thesis, concludes with a discussion of how the usefulness of the conceptual proposals might be further assessed and thus the implications for the next stage of the research process.

The first conceptual proposal, developed in Chapter 4, is a broad conceptualisation of emergence which addresses *SQ-E – what is emergence?* This contends that emergence may be profitably understood as (i) an inherently fuzzy concept, (ii) which is based around macro-level properties (emergents) which are not manifest in individual micro-level components in isolation and (iii) encompasses ontological, epistemological and complexity dimensions. This conceptual proposal establishes and broadly bounds the conceptual domain of emergence and, I argued, is epistemologically 'sound' while retaining its normative usage of the concept. These properties are critical to enabling the various existing conceptualisations to be legitimately understood within one conceptual framework. This in turn is vital if we are to successfully leverage the extant body of disciplinary knowledge and understanding regarding emergence. The broad conceptualisation has three further important implications for this research and for understanding emergence in general. Firstly, it offers a plausible means of resolving the ongoing definitional or conceptual dispute. Secondly, by establishing and bounding the conceptual domain, it allows us to clarify what type of knowledge we might expect to develop and what types of activities might be most profitable in the quest to improve understanding of emergence in all its forms. Finally, the broad conceptualisation is precisely that – broad – and therefore it needs further elaboration and, as the discussion of plausibility illustrate, there may continue to be a need to use examples to clarify meaning.

The second conceptual proposal, developed in Chapter 5, is a multi-tiered typology of emergence designed specifically to support interdisciplinary analytical discourse regarding emergence. The multi-tiered typology is based on the three general approaches to emergence and their subtypes and key characteristics which were identified in Chapter 2. Three properties are key to the profitability of the multi-tiered typology: it adequately spans the domain of interest; is locally consistent and globally coherent; and is conceptually founded.

This, I argued, means that the multi-tiered typology has three key advantages over existing typologies of emergence. Firstly, it elaborates the broad conceptualisation, offering a detailed description of what is meant by emergence. Thus, the multi-tiered typology further addresses *SQ-E – what is emergence?* Secondly, it provides a parsimonious framework for developing and conveying shared meaning of emergence within an interdisciplinary context. Thirdly, it provides a means of identifying boundary objects and their characteristics. Such objects are a key focus for exploring problems in interdisciplinary discourse.

The third conceptual proposal, developed in Chapter 6, is an explanatory framework designed to improve understanding of emergents. This, it was argued, is required as, while the broad conceptualisation and multi-tiered typology together establish and elaborate the concept of emergence, they are concerned with conceptual analysis of the concept of emergence. Therefore, they do not directly facilitate improved understanding of real-world emergents. Thus, the explanatory framework complements the first two conceptual proposals by directly addressing *SQ-RW – how might understanding of real-world emergent phenomena be improved?* The explanatory framework is specifically designed to develop 'neutral' but conceptually-relevant descriptions of emergents, their causation and their behaviour. It achieves this by assessing different epistemological factors that might affect the description, capturing the emergent and its causal environment, and making explicit exactly is meant by the key characteristics it identifies. These three requirements are necessary if existing difficulties in understanding emergence are to be minimised. The explanatory framework consists of four stages. Stage 1 identifies the emergent relation and the causal environment relating to the emergent; stages 2-4 are concerned with description of the key characteristics associated with the instantiation of the emergence relation, generation of the emergent and its causal powers respectively. The explanatory framework provides three important advantages over other approaches. Firstly, its 'neutral' but conceptually-relevant approach means that the descriptions may be used to support analytical discourse regarding emergents and emergence. Secondly, as the descriptions generated are grounded in real-world phenomena rather than particular conceptualisations of emergence, it allows the descriptions to be used to independently assess the usefulness of the broad conceptualisation and multi-tiered typology. Thirdly, by considering the physical and epistemological causal base of the emergent as opposed to simply the micro-level properties on which it is directly physically determined, the explanatory framework captures the complexities of physical and epistemological causation, thus I argued, offering an advantage of more traditional approaches which focus solely on physical determinism.

Each conceptual proposal performs a distinct role in the quest to improve understanding of emergence as the preceding summaries illustrate. All three conceptual developments, I argue, offer a valuable but distinct contribution. Firstly, the broad conceptualisation is necessary as it establishes the legitimacy of bringing together the various existing conceptualisations of emergence within one conceptual framework, which acts as a transdisciplinary bridge. Further, as the broad conceptualisation effectively bounds the conceptual domain, it provides valuable guidance as to what might realistically be considered as emergence within broad but normative usage. Secondly, the multi-tiered typology elaborates the broad conceptualisation. Without this elaboration, the broad conceptualisation, while having the potential to be conceptually rich, is unstructured save for its three dimensions. This, I argued, is problematic because within an interdisciplinary context, different meanings and norms will exist. Thus, the highly abstract broad conceptualisation cannot directly support detailed sound interdisciplinary analysis of emergence. Therefore the multi-tiered typology not only offers more detail on the conceptual structure of the concept of emergence but it also facilitates more detailed interdisciplinary and disciplinary conceptual analysis. This is critical if, as discussed in Chapter 1, we are to leverage the significant extant body of work on emergence. Finally, the explanatory framework directly addresses improving understanding of real-world emergent phenomena rather than conceptualisations of emergence. As it is not directly based on the broad conceptualisation or multi-tiered typology, it has the advantage that it can be used to test these proposals. However, I argued, it cannot replace these proposals as it has a very limited conceptual structure. Therefore, while it can support practical analysis of emergents, it cannot directly support more sophisticated conceptual analysis of emergence.

The plausibility of the three conceptual proposals was assessed in each of the preceding chapters. While all were found to be plausible, limitations were identified. The most significant issues concern the potential practical application of the proposals. This concern arises in large measure from the nature of phenomena that give rise to the concept of emergence, where ontological and epistemological factors combine, potentially in a non-linear manner, making fuller understanding difficult. Thus, the conceptual tools need to be practically assessed in order for it to be claimed that they are profitable. Assessment of the conceptual proposals and the research in general is the subject of Part III of this thesis and is addressed next.

Part III

Having proposed and analysed the plausibility and potential advantages of the three conceptual proposals – the broad conceptualisation of emergence, the multi-tiered typology and the explanatory framework for describing emergents – in Part II, attention is now turned in Part III to assessment of the conceptual proposals and the research itself.

First in Chapter 7, the profitability of the conceptual proposals is further assessed through use of real-world examples of emergence. This is achieved by first developing explanatory descriptions of example emergents using the explanatory framework which was presented in Chapter 6. The example emergents – seven in total – are taken from the list of classic examples of Chapter 2, section 2.2. Their descriptions are then used to further assess the plausibility and usefulness of the three conceptual proposals. Additionally, the analysis also draws on a separate empirical study of emergence in learning communities to substantiate the higher level analytical capabilities that the conceptual proposals are designed to support.

Part III, and the thesis, then draw to a conclusion in Chapter 8. Here the research is briefly summarised and its contributions discussed. This is followed by an assessment of the research results and the investigatory approach. The last step is to discuss future work.

Chapter 7 Assessing the conceptual proposals

The purpose of the conceptual developments presented in Part II is to help improve understanding of emergence. While it has been argued that the proposals themselves improve understanding as they offer a plausible explanation of some of the problems currently associated with emergence, a key purpose of the proposals is to further understanding through facilitation of coherent interdisciplinary conceptual analysis – i.e. the breaking down of the concept into subconcepts and their relationships, and the identification of the relation of emergence to other concepts. Without illustrating that the conceptual proposals support this, the claim to their potential usefulness cannot be reasonably assessed. Conceptual analysis which aims at revealing strict logical relationships between key characteristics is unlikely to succeed as fuzzy concepts do not entail strict logical relationships between subconcepts (Earl 2007); rather, identification of trends between subconcepts (e.g. key characteristics) is a much more realistic expectation where fuzzy concepts are concerned. Thus, if it can be shown that there is reasonable empirical evidence and logical reasons that support trends in relationships between subconcepts and related concepts in at least certain circumstances then this would, I would argue, constitute reasonable conceptual analysis. This chapter is therefore concerned with analysis of the relationships between the various subconcepts relating to emergence and what the results might tell us the conceptual proposals of Part II.

The starting point is to use the explanatory framework to develop descriptions of seven emergents, chosen from the classic examples of emergence first introduced in Chapter 2, section 2.2. As I will illustrate, these descriptions provide clarity regarding particularly problematic areas relating to understanding of the different emergents. While four potential issues with the development of the descriptions can be identified, these problems, I will argue, do not affect the fitness of the descriptions for use in conceptual analysis provided that the contextual information contained within the description is referred to and the descriptions are pragmatically revised when inconsistencies become apparent. Thus, these neutral but conceptually-relevant descriptions of real-world emergents provide a basis for examining the relationships between subconcepts of emergence and hence assessment of the capabilities of the three conceptual proposals. The plausibility of the broad conceptualisation of emergence can be further assessed through two forms of conceptual analysis. Firstly, the range of key characteristics held by the differing examples may be compared and contrasted. The results of the analysis, I will argue, further support the plausibility of the inherent fuzziness of emergence. Secondly, the extent to which ontological, epistemological and complexity-related factors need to be taken into consideration in order to adequately describe the emergents is considered. This, I will illustrate, supports the claim that emergence has ontological, epistemological and complexity dimensions. The profitability of the multi-tiered typology can be assessed by first loosely matching the descriptions onto the various types/subtypes of the typology. Using the results, I will shows that it is possible to explain why and under what circumstances a particular example might be considered emergent, thus illustrating its use as a comparison and generalisation tool. As the multi-tiered typology supports comparison across the broad conceptual space relating to emergence, it should also facilitate predictions and extrapolations to be made which span the boundaries of particular conceptualisations. To assess these higher level analytical capabilities, the loose matching of the classic examples and the multi-tiered typology will be used to predict why and in what circumstances other phenomena might be considered emergent and to extrapolate what types of characteristics such emergents may be expected to possess. I will illustrate the validity of these predictions and extrapolations, and hence the profitability of the multi-tiered typology, by comparing the predictions with the characteristics of two sample emergents taken from two pre-existing learning communities case studies. As the descriptions of the example emergents developed using the explanatory framework are at the core of the assessment of the profitability of the broad conceptualisation and multi-tiered typology, the analyses also, I will argue, help illustrate the usefulness of the explanatory framework. Further, as I will show, the analyses illustrate the need to drill down regarding what exactly is meant by a key characteristic and why it might be interpreted very differently due to epistemological perspectives. Hence this, I will claim, further supports the rationale for the form of the explanatory framework as well as its coverage.

The chapter proceeds as follows. In section 7.1, neutral but conceptually-relevant descriptions of real-world emergents are developed. Next, in section 7.2, the descriptions are discussed to assess their fitness for conceptual analysis and their implications for the explanatory framework. Conceptual analysis using the descriptions is then undertaken in section 7.3 in order to further assess the three conceptual proposals presented in this thesis. The chapter concludes, in section 7.4, by summarising the developments and identifying the next stage in the research process.

7.1 Description of example emergents

In this section the explanatory framework is employed to develop neutral but conceptually-relevant descriptions of seven emergent phenomena. The examples are selected from the list of classic examples of Chapter 2, section 2.2. Following Doty and Glick's (1994) advice (see Chapter 3, section 3.2.3, p135) the example emergents are selected to include both typical and interesting cases. In particular, they aim to capture key areas of disagreement regarding emergence. Before proceeding to these descriptions, five observations regarding the application of the explanatory framework are made.

Firstly, as is inevitable in any conceptual analysis, perception and conceptualisations will influence the analysis. For example, if we fail to take quantum mechanics into account, the chemical properties of ammonia will be irreducible. For clarity, the most appropriate theory and scope is used in the explanatory framework analysis – i.e. current 'best understanding' is adopted. Thus, in the discussion of the chemical properties of ammonia in subsection (c), the entry for *Predictability of emergent/Scope* in Table 7-7 is 'No', indicating that the degree of reducibility will not be improved by adoption of an increased scope or resolution.

Secondly, epistemological factors are only highlighted where a different set might reasonably be expected to change the perception of the emergent or its characteristics. As a result, on occasion, the 'simplest' scope is not adopted; rather another scope which is particularly insightful or represents an earlier misunderstanding is used in order to draw out a significant point. Such uses will be clearly marked.

Thirdly, '/' separates alternative interpretations and '( )' is used to indicate areas of contention in the summary tables corresponding to the analysis of meta-relational characters, generators or causal powers of emergent. For example, in subsection (c), it is argued that the smell of ammonia is predictable in principle provided the role of nasal receptors is considered. However, the smell was interpreted as unpredictable by the early British emergentists because they failed to adopt an adequately wide scope. This is captured in Table 7-7, by *'In principle/(Unpredictable)'* in the entry relating to the predictability of the realisation of the smell of ammonia and *'No/(nasal receptors)'* in the entry relating to scope.

Fourthly, multiple potential emergent relations may be analysed in parallel. This is carried out for two reasons: (i) to compare and contrast the results of slightly different foci of investigation or (ii) where the emergence under consideration actually consists of multiple, possibly interrelated emergents. While concentrating on one or two particular micro-macro relations, the implications of slightly different approaches to the micro-macro relation under consideration are also discussed where relevant.

Finally, in order to accommodate the preceding issues, the outputs of the explanatory framework are presented as a discussion rather than as a definitive description. This, I would argue, is beneficial as it helps make explicit any underlying assumptions and where different perspectives might give rise to differing explanations. Further, it allows for the fact that explanation depends to a large extent on purpose and context. However, it does mean that the explanatory descriptions are still full of caveats. This, in my view, is an inevitable consequence of the nature of emergence and indeed explanation.

The section proceeds as follows. In subsections (a) - (g), seven 'classic' emergents selected from the list of Chapter 2, section 2.2 are considered. The descriptions start with the 'simplest' forms of emergence – (a) the property of being a circle',
(b) thermodynamic properties – moving to more difficult – (c) the smell of ammonia, (d) the functionality of a machine – and finally complicated if not complex forms – (e) the World Wide Web, (f) life and (g) mind – as the subsection proceeds. While the descriptions of the simpler examples may seem laborious, they are used to clarify points which might be obscured in the more complicated examples. They, thus, highlight interesting points and afford insights in their own right. The examples of subsection (f) and (g) are much more complex and less well understood and hence their assessment is somewhat limited. However, the issues that are uncovered are in themselves informative. These descriptions of the 'classic' example emergents are developed from a synthesis of extant literature using the explanatory framework. Each description ends with a summary of the improved clarity that it affords.

(a) Property of being a circle

The emergence system and emergence relation(s) associated with the property of being a circle

Bedau's claim that the property of 'being a circle' is emergent was introduced in Chapter 2, subsection 2.3.1. Bedau (2002) defines the emergence relation as the relation between the geometric points which constitute the circumference and the circle itself. While intuitively this might not appear to be emergent according to many approaches to emergence, it poses the question of why is the macro-level property apparently not contained in the micro-level components?

Clearly the relationship between the geometric points which constitute the circumference and the circle itself is a logical relation, although dynamics must be involved in the construction of the circle. The key organisational feature of the associated emergence system is the micro-macro relation – multiple layers, heterogeneity and subjectivity do not play an organisational role in the emergence. Provided that the scope of observation is sufficiently wide to observe the whole circle, it is unlikely that a wider scope, new resolution or observation will improve understanding of the emergent. Figure 7-1 below summarises the emergence system associated with the property of being a circle.

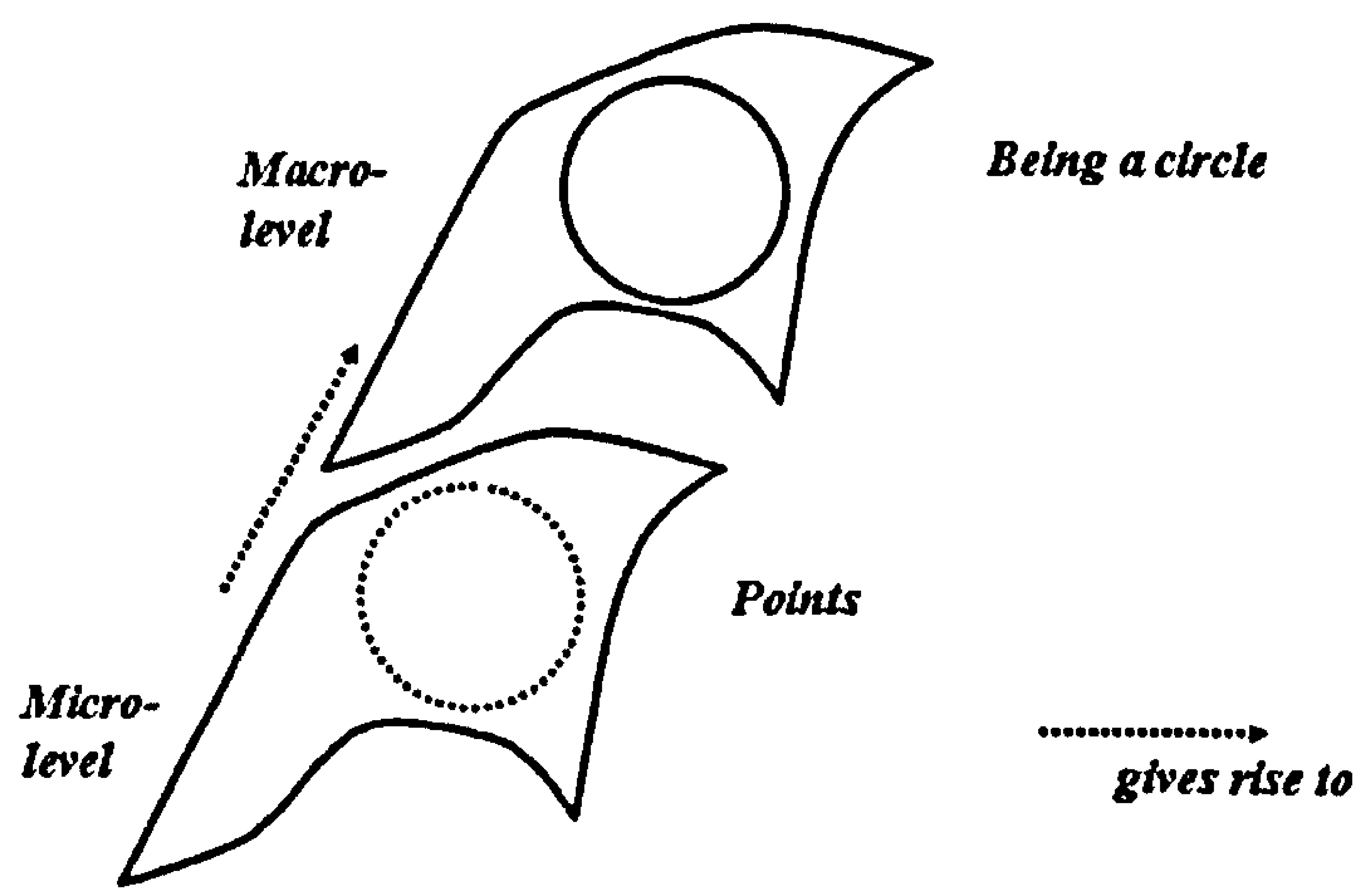

Figure 7-1: Overview of the emergence system and emergence relations associated with the property of being a circle

This emergence of the property of being a circle from its component points is discussed further in the following subsections.

Meta-relational properties of the emergence of the property of being a circle

There is no surprise or unpredictability involved when considering the emergence of the property of being a circle. Further, as the equation of a circle – $(x-a)^2 + (y-b)^2=r^2$ – fully defines every point on the circumference of the circle, it is fully deducible and explainable in terms of its component parts and their relation. Establishing the degree of reducibility is not so simple. Intuitively the property of being a circle is reducible to its component parts. But is it reasonable to view it as being contained in each component part? For example, it was argued in Chapter 2, subsection 2.2(i) and Chapter 6, subsection 6.1.2 Table 6-1 that the weight of a bag of apples is contained in the sum (i.e. aggregation) of the weight of each of the apples. The answer depends on the frame of reference adopted. If the individual points are viewed as Cartesian points on the x-y plane, then it is the sum of their individual geometric properties which gives rise to the property that they form a circle. Alternatively, it could be argued that each point must be in a specific geometric relation to the other points and so the property of being a circle is the product of the individual points. As discussed in the introduction to this section, the simplest view which provides a satisfactory understanding should be adopted. Thus, with the caveat that this is dependent on perspective, I would argue that the property of being a circle is reducible to a sum of the properties of its component parts. Neither different scope nor resolution will improve the predictability or reducibility.

The meta-relational properties of the emergence of the property of being a circle are summarised in Table 7-1 below.

Meta-relational property		**Property of being a circle**
Surprise		No
Predictability of emergent		Readily Predictable
	Scope	No
	Resolution	No
Reducibility of explanation		Sum
	Scope	No
	Resolution	No

Table 7-1: Analysis of the meta-relational properties associated with the property of being a circle

Generators of the property of being a circle

There are no component level constraints as there is no direct relationship between any two points on the circle, nor is there any relational constraint. Rather the points are dictated by the equation of a circle as the points must satisfy this equation if it is to be a circle. Thus, I would argue, the equation of the circle may be viewed as acting as a macro-level constraint.

While a circle is clearly non-linear in nature, it is not really a result of non-linear dynamics as it is not formed by the interaction of related (coupled) points. Even in the case of a circular water wave, which is formed by displacement of independent molecules of water, coupled interaction between wave front particles does not drive the development of the circle – the wave front radiates out from all directions. Thus, in general, circles might reasonably be viewed as 'manufactured'. Further, in most cases a circle is designed, although it may occur naturally as in the circular water wave example. Prior emergence and internal subjectivity also do not play a causal role.

As a circle is a circle, independent of whether someone observes it, observation is not a generator. Similarly, reasoning does not contribute to the generation of the property. Scope does not play a role as widening the scope does not make the property disappear. Resolution, I would argue, potentially affects perceived generators but not their type. For example, the equation of a circle was identified as a macro-level constraint. However, even if we did not know this equation the macro-level constraint still exists as the system itself dictates that the individual points on the circumference have particular geometric properties – if they do not, they cannot give rise to a circle.

Analysis of the generators of the property of being a circle is summarised in Table 7-2 below.

Generators		**Property of being a circle**
Generators of macro-level properties	*Component constraints*	No
	Macro constraints	Yes
	Relational constraints	No
Construction	*Self-organisation*	No
	Manufacture	Yes
	Design	Yes
	Prior emergence	No
	Subjectivity	No
Epistemo-logical generator	*Observation*	No
	Reasoning	No
Epistemo-logical influence	*Scope*	No
	Resolution	No

Table 7-2: Analysis of the generators of the property of being a circle

Causal powers associated with the property of being a circle

The property of being a circle does not have any macro-level causal powers. Further, as its component parts do not engage in any dynamical behaviour, there is no downward causation. This is independent of scope or resolution. Table 7-3 below provides a summary of the causal powers analysis.

Causal power	**The property of being a circle**
Macro-level	No
Scope	No
Resolution	No
Downward causation	No
Scope	No
Resolution	No

Table 7-3: Analysis of the causal powers of the property of being a circle

Conclusions regarding the emergence associated with the property of being a circle

The property of being a circle is not normally considered emergent. However, Bedau argues that this property is global as is not held by the individual points that make up the circle. Thus, it satisfies, if somewhat trivially, criterion (ii) of the broad conceptualisation of emergence. As the emergent is both readily deducible and reducible, the emergent can be fully understood in terms of its component parts and as it does not display any causal powers, the emergence appears totally trivial and purely epistemological. Even unpredictability does not play a role in its perception as emergent. However, as the preceding descriptive analysis illustrates, the key generator of the emergent is the macro-level rule of being to a circle as this acts as a constraint, excluding points which do not comply with the constraint. It is this macro-level constraint that gives rise to the apparent macro-level property of being a circle, which is not contained in its micro-level components.

(b) Thermodynamic properties

The emergence system and emergence relation(s) associated with thermodynamic properties

In Chapter 2, subsection 2.2(e), thermodynamic properties such as temperature, pressure and entropy were suggested as examples of emergence because these properties do not appear to exist at the level of the constituent parts. Here, the emergence relation is the relation between constituent particles of a system and the global thermodynamic properties of the system. The system could range from an isolated gas to the environment of a room. This relation is generally perceived as logical (synchronic) in nature although dynamics play a part in the realisation of the thermodynamic properties as they arise from the kinetic energy of the component particles. While pressure appears to be simply explainable in terms of micro-level component properties and behaviour, temperature and entropy are much more interesting cases. Temperature and entropy, at least as they were originally understood, are macro-level concepts. The associated emergence system is captured in Figure 7-2 below.

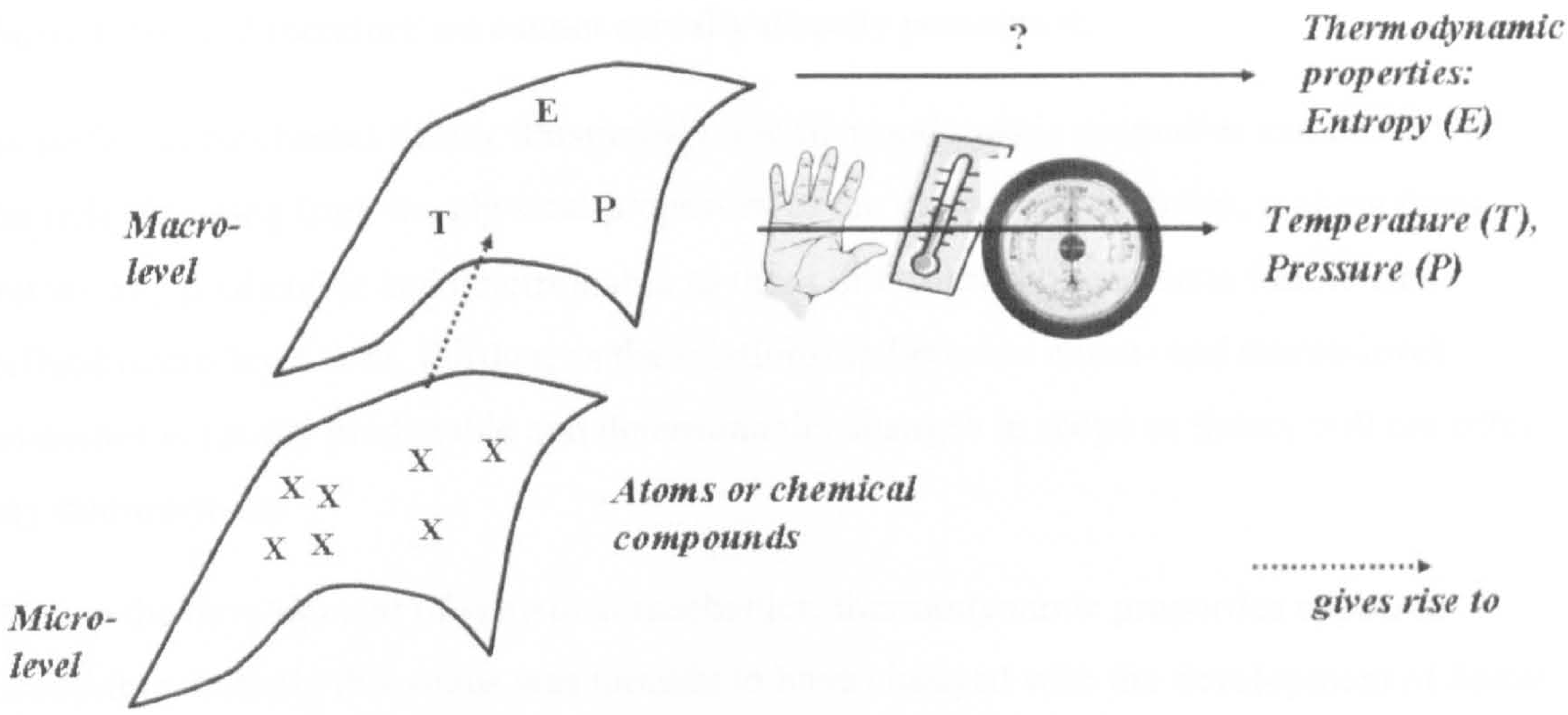

Figure 7-2: Overview of the emergence system and emergence relations associated with thermodynamic properties

As Figure 7-2 above illustrates, temperature is realised through some sort of measuring device be it a thermometer or touch. However, although the existence of entropy is the central tenet of the 2nd law of thermodynamics, entropy cannot be directly observed; rather it is a result of observed relations between other thermodynamic properties. It was formerly interpreted as a measure of the disorder in a system, although it is now conceptualised as a measure of unavailability of a system's energy (Daintith 2005).[56] The scientific meaning of temperature has also evolved over time from our everyday experience of temperature as something we can feel to a property held by two macroscopic objects in equilibrium. Thus, epistemological considerations are likely to play a significant role in understanding temperature and entropy.

It is this role that epistemology potentially plays that has led to considerable discussion as to whether thermodynamic properties are mere epiphenomena and thus makes thermodynamic properties an appropriate 'interesting case'. The emergence relations between the property of the micro-level system particles and thermodynamic temperature and entropy respectively are considered in more detail in the following sections.

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[56] http://en.wikipedia.org/wiki/Entropy provides a history of the concept of entropy.

Meta-relational properties of the emergence of thermodynamic properties

Temperature is part of our every day experience and its nature cannot really be classed as a surprise. Entropy is much more surprising as there is no direct method of measurement (Sklar 1999) and therefore we cannot actually directly perceive it.

As statistical mechanics theory illustrates, these thermodynamic properties can be derived through averaging from the physical properties of the constituent particles, making them statistically predictable and determinable as these micro-level phenomena follow well defined micro-level laws. Further, as the relationship between micro- and macro-level properties is readily predictable and determinable, changes in scope or theory will not offer any improvement.

Prior to the development of statistical mechanics, thermodynamic properties appeared irreducible. Initially this status was thought to have changed with the development of linear statistical mechanics, where temperature may be explained by attributing it to the kinetic energy of the average idealised particle within a substance. As temperature is meaningless at the individual particle level, the explanation is achieved through reduction and conceptual translation. However, within thermodynamics it is equally acceptable for electromagnetic radiation to have a temperature (Sklar 1999, p194) and so not all realisations of thermodynamic temperature are reducible to classical statistical mechanics, although reduction to quantum mechanics might, in principle, be feasible.

Explanation of the thermodynamic concept of entropy in terms of statistical mechanics at first appeared even more problematic as there was no equivalent micro-level concept or conceptual translation. However, new understanding has recently led to the reformulation of the concept itself, defining entropy through a statistical ensemble approach as the number of microscopic configurations that result in the observed macroscopic description of the thermodynamic system. Thus, entropy now has a micro-level definition, although this definition makes reference to macro-level properties. So, I argue, macroscopic entropy does not fit neatly into either the reducible to a sum or product categories of reducibility.

Sklar also more fundamentally questions how non-statistical concepts appearing in thermodynamics can be reduced to statistical/ensemble quantities that are core to statistical mechanics[57]. So the best that can be said is that the reducibility of explanation is

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[57] See Batterman (2005) for further objections to the reducibility of thermodynamics.

questionable. Increased scope is unlikely to change perception of reducibility; however new theory may provide further insights.

These meta-relational properties of the emergence of temperature and entropy are summarised in Table 7-4 below.

Meta-relational property	**Thermodynamic temperature**	**Thermodynamic entropy**
Surprise	No	Yes
Predictability of emergent	Readily Predictable	Readily Predictable
Scope	No	No
Resolution	No	No
Reducibility of explanation	'Sum'[58] + Conceptual translation	'Sum'+ macro-level factor
Scope	No	No
Resolution	Possibly	Possibly

Table 7-4: Analysis of the meta-relational characteristics associated with thermodynamic temperature and entropy

Generators of thermodynamic properties

Although there is a macro-level reference in the micro-level definition of entropy this does not constrain the behaviour of the micro-level and so is not a generator. Further as thermodynamic properties are explained in terms of a non-linear statistical average would suggest that construction also does not play a part in their generation.

The role of potential epistemological causal factors is more interesting. For example, while we feel temperature, what we actually sense is the transfer of heat energy between ourselves and the environment. This heat energy arises from the kinetic energy of atmospheric particles or from infrared radiation. So, temperature is arguably a result of our sensory apparatus. However, its existence is not theory or reasoning dependant – we sense temperature whether we understand the theory of how it arises or not. Entropy is quite different. We do not perceive it directly but it has become a well established and critical

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[58] Scare quotes are used as it is a statistical average rather than a simple sum.

concept in thermodynamic theory. So the concept of entropy at least can be viewed as a partial result of our reasoning; however, reasoning cannot be said to play a causal role in the disorder or unavailability of energy in a system.

A wider scope or resolution is unlikely to change the perceived generators.

Analysis of the synchronic and diachronic generators of thermodynamic properties is summarised in Table 7-5 below.

Generators		**Thermodynamic temperature**	**Thermodynamic entropy**
Generators of macro-level properties	*Component constraints*	No	No
	Macro constraints	No	No
	Relational constraints	No	No
Construction	*Self-organisation*	No	No
	Manufacture	No	No
	Design	No	No
	Prior emergence	No	No
	Subjectivity	No	No
Epistem -ological generator	*Observation*	Yes	No
	Reasoning	No	(Yes)
Epistemo -ological influences	*Scope*	No	No
	Resolution	No	No

Table 7-5: Analysis of the generators of thermodynamic temperature and entropy

As Table 7-5 above suggests, the emergence of thermodynamic properties might reasonable be viewed as purely epistemological in nature.

Causal powers associated with thermodynamic properties

Thermodynamic properties participate in macro-level laws and therefore may be considered to have macro-level causal powers. For example, 'Charles law' states that V/T=k, where V is volume, T is temperature and k is a constant. While the majority of these laws are reducible to those of the average of micro-level component properties, there are significant exceptions.

For example, the second law of thermodynamics states that the total entropy of an isolated system tends to increase over time. Thus, the thermodynamic property of entropy has a distinct arrow of time which statistical mechanics does not (Sklar 1999, Silberstein 2002). The origin of this time asymmetry is one of the fundamental puzzles of modern day physics and indicates an apparent irreducibility. While it is unlikely, I would argue, this will become fully reduced, improved theoretical understanding may make the entropy arrow weakly reducible in future. Thus, the degree of macro-level causal powers may be subject to resolution.

Thermodynamic properties do not display irreducible downward causal influence on the constituent particles as they are fully realised through the properties of the constituent particles. Nor can temperature, for example, be said to constrain the activities of the micro-level particles or their future dynamics. Hence thermodynamic properties do not display downward causation.

The analysis of causal powers of thermodynamic temperature and entropy is summarised in Table 7-6 below.

Causal power		**Thermodynamic Temperature**	**Thermodynamic Entropy**
Macro-level		'Sum'	Possibly irreducible
	Scope	No	No
	Resolution	No	Possibly
Downward causation		No	No
	Scope	No	No
	Resolution	No	No

Table 7-6: Analysis of the causal powers of thermodynamic temperature and entropy

Conclusions regarding the emergence associated with thermodynamic properties

Examination of the emergence associated with the thermodynamic properties highlights the significant role that our perceptual devices play in emergence. There are no physical constraints associated with the generation of the emergence; rather the emergents – macro-level properties such as temperature and pressure – appear to be the result of measurement at a specific scale. This means that they are wholly physically determined by the component parts – the individual atoms which make up the substance under investigation *and* a measuring device. Entropy, on the other hand, cannot be directly observed; rather the concept came into being for theoretical reasons. Thus, the generators of the thermodynamic properties appear epistemological in nature.

The analysis of causal powers highlights that while, on the surface, thermodynamic properties appear mere epiphenomena (the result of our perceptual devices), the arrow of time which entropy appears to give rise to, indicates that explanation of some of their causal powers is irreducible at present. Finally, as the summary of analysis of meta-relational characteristics in Table 7-4 illustrates, neither temperature nor entropy fit readily into the types of reducibility identified within the explanatory framework of Chapter 6 (see Table 6-1), again indicating the role that our perceptual devices play.

In conclusion, thermodynamic temperature does appear to be explainable in terms of micro-level components and our perceptual devices and therefore may be considered an epiphenomenon. However, to understand its macro-level features we must take into account our perceptual devices. Entropy, on the other hand, given current levels of understanding at least, cannot be fully explained in a similar manner.

(c) The smell of ammonia

The emergence system and emergence relation(s) associated with the smell of ammonia

As the discussions of Chapter 2, subsection 2.3.2(b) and Chapter 6, section 2.4.4 illustrate, classifying the smell of ammonia as emergent has been widely disputed, with several different interpretations of what exactly constitutes the emergence relation. The smell of ammonia is considered a candidate for emergence because its constituent elements – hydrogen (H) and nitrogen (N) – do not possess the distinctive smell which their compound does. But, as discussed in Chapter 2, subsection 2.2(f), while the analysis by the early British emergentists solely examined the relation of the smell to the constituent hydrogen and nitrogen atoms, it is only in the presence of nasal receptors that the smell is realised. So, to understand the smell of ammonia, we need to understand both how the compound ammonia has the property that it gives rise to the distinctive smell and how that smell is realised. Figure 7-3 below illustrates the extent of the emergence system that needs to be considered.

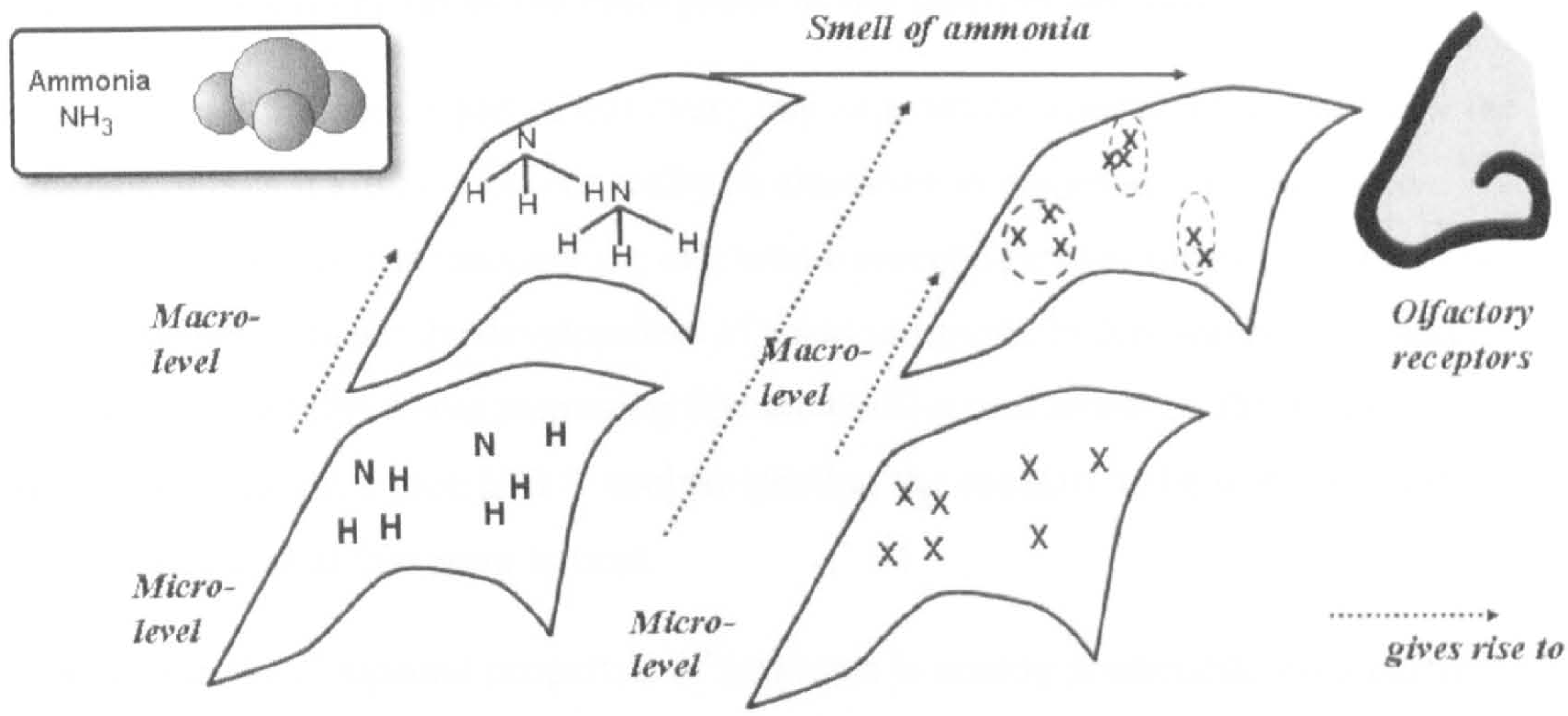

Figure 7-3: Overview of the emergence system and emergence relations associated with the smell of ammonia

As Figure 7-3 above illustrates, while the smell of ammonia is clearly a macro-level property, it is not physically determined by nitrogen and hydrogen alone; the chemical and physiological structure of the olfactory receptors also plays a part. Thus three different emergence relations can be identified: (i) the arising of the property of the potential to give rise to the smell of ammonia from the constituent chemical elements of ammonia[59]; (ii) the arising of the olfactory receptors from its constituent biological cells and (iii) the realisation of smell of ammonia from the compound properties of ammonia and the olfactory system. The emergence relations associated with the chemical properties and the realisation of the smell are considered in the following subsection, where for shorthand they are referred to as 'compound properties' and 'realisation of smell' respectively. The emergence relation associated with the olfactory receptors is not considered in detail for simplicity although it is referred to where relevant.

Figure 7-3 also illustrates that the interaction of two emergents – ammonia and nasal receptors – is involved. Thus, the issue of different levels of organisation may arise. Finally, for clarity of discussion, the ongoing emergence associated with the smell of ammonia will be considered rather than its initial occurrence.

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[59] The existence of a property of 'having the potential to' is of course questionable. Here it is used as a shorthand for a specific set of chemical properties which under the right circumstances will give rise to the smell of ammonia.

Meta-relational properties of the emergence of the smell of ammonia

As the smell of ammonia is part of our every day experience, even if we do not know the mechanics of how it arises, it cannot really be classified as surprising. The possible exception is, if we were to consider the diachronic emergence over time of the realisation of the smell which included the development of nasal receptors. In this scenario it could possibly be argued that it was surprising that the smell arose; however, this is not a particularly sound deduction as it is unclear whether the capacity to be surprised at this occurrence existed at that point in time.

The arising of the compound properties of ammonia is readily predictable from current theoretical understanding of quantum mechanics. Claiming anything is readily predictable from quantum mechanics may seem contentions. The term readily predictable is used here to capture the fact that chemical properties can and have been predicted from application of quantum mechanics – one single theory. On the other hand, the realisation of the smell at a given instant should, I would argue, be considered predictable in principle only, as multiple layers of emergence are involved. Indeed, predictability, in principle, is true only provided that the role of nasal receptors – i.e. appropriate physiology – is considered. If, as in the case of the early British emergentists, a narrower scope is adopted, the smell is unpredictable.

Given current theoretical understanding, the explanation of the compound properties of ammonia is reducible as it is a simple product of the properties of hydrogen and nitrogen. Explanation of the realisation of the smell is much more interesting, illustrating the effect of the scope of observation. Explanation of the smell is arguably irreducible when the role that nasal receptors play is not considered. On the other hand, as the properties of both ammonia and nasal receptors are arguably reducible to a product of the properties of their constituent chemical components, the realisation of the smell is reducible to a complex product of the constituent chemical components when the scope also includes nasal receptors. The product, I would argue, is complex as it involves the interaction of multiple types of component chemicals and potentially multiple layers of emergence. For example, the nasal receptors themselves are part of a wider olfactory system which has its own 'rules'.

The meta-relational properties are summarised in Table 7-7 below.

Meta-relational property	**Compound properties**	**Realisation of smell**
Surprise	No	No
Predictability of emergent	Readily predictable	In principle/

Meta-relational property	**Compound properties**	**Realisation of smell**
		(Unpredictable)
Scope	No	No/ (No nasal receptor)
Resolution	No	No
Reducibility of explanation	Simple product	Complex product/ (Irreducible)
Scope	No	No/ (No nasal receptors)
Resolution	No	No

Table 7-7: Analysis of the meta-relational properties associated with the emergence of the smell of ammonia

Generators of the smell of ammonia

The chemical characteristics of the compound formed from hydrogen and nitrogen are at the core of the emergence of the smell of ammonia and so component constraints – the bonds between components – are core generators of the emergents. The realisation of the smell also clearly depends on relational constraints – the relation between the compound properties of ammonia – and the nasal receptors as the individual component parts would not directly give rise to the smell. Macro-level constraints are not in evidence.

Self organisation is the main construction process of the smell of ammonia, driving both the formation of the compound ammonia from its constituent chemicals and the evolution which led to nasal receptors. Thus, prior emergence is also integral to the emergence of the smell. If the wider emergence system is examined, the fact that the nasal receptors can distinguish ammonia from other chemicals, I would argue, is a causal factor in the realisation of the smell. Thus, the nasal receptors may be viewed as acting subjectively on the ammonia compound to generate the smell. Neither manufacture nor design contributes to the emergence *per se*, although clearly ammonia could be the result of a manufacturing process.

Our perceptual devices arguably play a role in the realisation of the smell as it involves stimulation of our olfactory receptors which sends signals to the brain. Thus, 'observation' should be considered as a causal factor in the realisation of the smell. However, 'reasoning' does not play a causal role.

As we arguably have scientific understanding of the causes of the compound properties of ammonia and how the smell is realised, wider scope or resolution are not expected to change the perception of generators.

The analysis of the generators of the compound property of the potential smell of ammonia and its realisation are summarised in Table 7-8 below.

Generators		Compound properties	Realisation of smell
Generators of macro-level properties	*Component constraints*	Yes	Yes
	Macro constraints	No	No
	Relational constraints	No	Yes
Construction	*Self-organisation*	Yes	Yes
	Manufacture	No	No
	Design	No	No
	Prior emergence	No	Yes
	Subjectivity	No	Yes
Eipstemo -logical generators	*Observation*	No	Yes
	Reasoning	No	No
Eipstemo -logical influence	*Scope*	No	No
	Resolution	No	No

Table 7-8: Analysis of the generators of the emergence of the smell of ammonia

Causal powers associated with the smell of ammonia

The compound of ammonia and its properties take part in chemical reactions and therefore may be said to have a form of macro-level causal power. The interaction with nasal receptors is a prime example and as discussed earlier, it is reducible to a product of the properties of its constituent parts. While the existence of the compound of ammonia and its properties means that the activity of the individual hydrogen and nitrogen atoms is constrained by chemical bonds, this arises from micro-level – quantum mechanics – rules and not from macro-level activity. Thus, I would argue, there is no downward causation associated with the compound properties of ammonia.

Physiological responses are stimulated by the interaction of the compound properties of ammonia and the nasal receptors and so the realisation of the smell of ammonia may be said to have macro-level causal powers, which are reducible to a product of the relevant micro-level component parts. Again, there is no obvious downward causation associated with the smell itself as any constraints on individual atoms are really the result of the ammonia compound or nasal receptors.

Analysis of the causal powers of the compound property of the potential smell of ammonia and its realisation are presented in Table 7-9 below.

Causal power		**Compound properties**	**Realisation of smell**
Macro-level		Product	Product
	Scope	No	No
	Resolution	No	No
Downward causation		No	No
	Scope	No	No
	Resolution	No	No

Table 7-9: Analysis of causal powers of the smell of ammonia

Conclusions regarding the emergence associated with the smell of ammonia

Examination of the emergence associated with the smell of ammonia exemplifies how emergents may be relational properties. In this example, the emergent is the distinctive smell and as Figure 7-3 above illustrated, it exists only in the relation between the compound ammonia and nasal receptors. As a result of this relation, the analysis of the realisation of the smell of ammonia in particular illustrates that scope is a significant factor in perception of the key characteristics of the emergent. As the smell is physically determined by the component parts of ammonia – hydrogen and nitrogen – *and* the nasal receptors, if the smell is to be fully explained, both must be included in the scope of investigation.

The discussion of the smell of ammonia also illustrates how multiple emergents add to difficulties in explanation. Analysis of the irreducibility of the emergence relation or the causal powers is more complicated if not complex as the existence of the smell lies between the ammonia and nasal receptors – two different emergents. Thus, the organisation of the emergence system in which the smell arises is key to its explanation. Further, the splitting up of the analysis into different emergents and how they are related is particularly useful in clarifying how components and characteristics are related. While the emergence of the smell is, I would argue, reducible to a complex product, of the constituent parts of the two emergents, I would contend that an explanation of the smell of ammonia which concerns only micro-level chemical components is highly unlikely to be of any practical use even if it could be achieved in practice.

(d) Functionality of a machine

The emergence system associated with the functionality of a machine

In Chapter 2, subsection 2.2(h), the functionality[60] of a machine is suggested as a potential emergent because it is a novel global property which is not held by the components from which the machine is constructed. As in the case of the smell of ammonia, agreeing what exactly the emergence relation might be has proven an area of disagreement in the past. Thus, if we are to try to explain the functionality of a machine, we need to start by clarifying what functionality is, how it relates to a machine and what other relevant factors to consider.

The term functionality describes the set of tasks that a machine may perform. So, for example, a function of a clock is to keep time, a function of a motor car is to transport people in a motor vehicle and a function of a computer is to carry out computations. The functionality of a machine may include several different functions and these functions may be planned our unplanned. For example, a car cigar lighter receptacle was originally designed to heat a cigar lighter. Nowadays, it is equally likely to be used to provide electrical power to a range of portable equipment such as iPods, mobile phone or coolers (See http://en.wikipedia.org/wiki/Car_Cigar_Lighter). Functionality, I would argue is not an innate characteristic of a machine as it would not exist without human input. Machines do have innate macro-level properties which are, by definition, fully physically determined by the component parts of the machine. For example, an innate property of a motor car is that it has a motor which turns its wheels. However, for it to have the function that it can transport people or things requires first that this possibility be appreciated. This conceptualisation at

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[60] The term functionality denotes a set of characteristics or attributes, where function is used to denote that work of some sort is carried out.

the very minimum would be in terms of the actions that it could be required to perform the task – i.e. it may be conceptualised in terms of getting from A to B rather than as transportation. Thus, I would argue, functionality lies in the relationship between the machine, the task(s) which it performs and the agents who conceptualise it. Additionally, functionality, in many cases, cannot be fully understood without recourse to external factors. For example, if the task of the machine is to do some work on an object then the function cannot be fully understood without recourse to the object on which the work is done. As illustrated in Figure 7-4 below, all these components and the surrounding environment must be considered as part of the 'emergence system'.

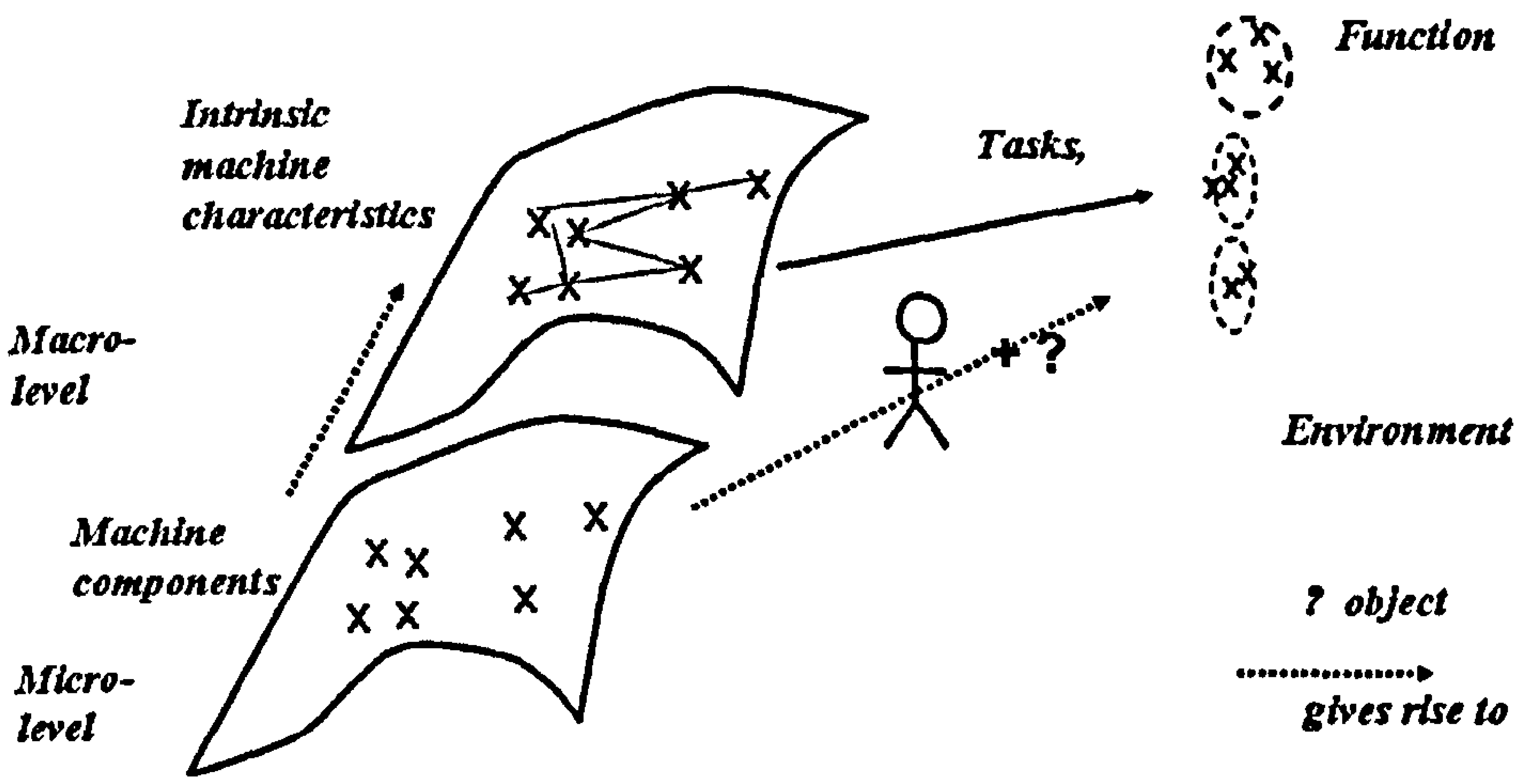

Figure 7-4: Overview of the emergence system and emergence relations associated with the functionality of a machine

As Figure 7-4 above identifies, one emergence relation is the relation between the intrinsic characteristics of the machine – i.e. the characteristics which give it the potential to carry out a task – and the component parts of the machine from which it arises. Additionally, a second emergence relation of the component parts to the realisation of the function can be identified. These two emergence relations are considered, the latter being assessed from two perspectives – planned and unplanned functionality.

Meta-relational properties of the emergence of the functionality of a machine

The planned intrinsic characteristics[61] and the planned functions of a machine are clearly not a surprise. Conversely, the unplanned function is surprising, although the function may seem

[61] Not all intrinsic characteristics are planned. For example, a clock which loses two seconds each day may have been designed to keep accurate time. Further, characteristics may arise through environmental factors. For example, due to wear and tear or environment conditions the clock may

obvious with the benefit of hindsight. The same holds for the predictability of the function, with unpredictability of the unplanned functionality arising from unknown and complex environmental factors and human agency rather than innate non-linear characteristics of the machine's micro-level components. However, at a given point in time, the unplanned functionality of a machine may not even be predictable in principle as the conditions which give rise to it may not yet have occurred. For example, did the unplanned functionality of a cigar lighter receptacle exist before such portable electrical equipment was even invented? This seems unreasonable, since when the cigar lighter was first invented, there was no guarantee that such portable equipment would be invented or used in a car. So, predictability depends on the scope, in time and environment, of the analysis. It is also possible that better understanding of how people innovate or use technology might have increased the predictability. Once a new function has initially been conceived, the function is predictable.

The explanation of the innate characteristics of a machine is reducible to a simple product of its component parts. If we take, as our micro-level base, the components of a machine, then it is clear that we cannot explain a function by reference only to the product of the properties of the components– we need to include not only the micro-level components but also the task that the machine undertakes to serve the function. Tasks are in effect processes and can be explained in terms of a series of actions. Thus, I would argue, the explanation of a function is reducible to the component parts of the machine plus the actions of the task which the function serves. Additionally, in the case of unplanned functionality, apparent irreducibility of explanation may also arise due to lack of theory or understanding of the new function, often leading to new epistemological theorising in order to arrive at an explanation. Further, the human agency involved in the arising of the new function may also need to be considered depending on the purpose of the explanation – i.e. is it to explain the actual function or how it arose?

The meta-relational properties of the emergence of the function of a machine discussed above are summarised in Table 7-10 below.

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later have the characteristic that its gains time. However, for simplicity sake only the planned intrinsic characteristics are considered here. The case of unplanned characteristics can be extrapolated from the case of planned characteristics and unplanned functionality.

Meta-relational property	**Characteristics of a machine**	**Planned function**	**Unplanned function**
Surprise	No	No	Yes
Predictability of emergent	Readily predictable	Readily predictable	In principle/ (Unpredictable)
Scope	No	No	(Time, Environment)
Resolution	No	No	Possibly
Reducibility of explanation	Simple product	Complex product+ sum of actions	Complex product/ (Irreducible)
Scope	No	No	(Time, Agency, Environment)
Resolution	No	No	Possibly

Table 7-10: Analysis of the meta-relational properties associated with the emergence of the function of a machine

As shown in Table 7-10 above, it is the scope and theoretical/conceptual foundation of the analysis which are the critical factors in the meta-relational properties relating to the functionality of a machine.

Generators of the functionality of a machine

Component-level constraints arising from the constituent parts of a machine are key to the development of the machine characteristics and both planned and unplanned functions. For example, the ability to keep time arises from the component cogs and wheels or chips and electric circuits of a clock. Further, where serving the function involves doing work relating to an external object then relational constraints will be involved. Where the machine is designed to serve a specific function, both the macro-level machine characteristics and the planned function might reasonably be considered as generated from a macro constraint – the function for which it was designed.

The case of unplanned functionality is more complicated as it does not arise from a direct macro constraint. Consider the case of cellular automata, which were originally designed to explore self-replication (von Neumann 1966). Since their conception, it has been discovered that certain cellular automata have the additional, unplanned property of 'acting like a Turing

Machine'. This means that they now have an additional function - to carry out computations[62]. In this case, the additional functionality develops from human recognition of the additional capabilities of the automata. As I have argued in the discussion of the associated emergence system, functionality cannot be considered independently of humans. Thus, this illustrates subjectivity within the emergence system itself. The same can be said for the case of the unplanned functionality of a cigar lighter receptacle in a car. Additionally, in this case the function exists between the cigar lighter receptacle and the portable electrical equipment and thus as both are 'machines' in their own right with emergent characteristics, thus prior emergence plays a causal role too. The same will hold for planned functionality

Whether prior emergence plays a causal factor in the development of the macro-level machine characteristics depends on what the micro-level components of the emergence system are taken to be. If humans are a micro-level component then prior emergence does not play a significant role. On the other hand if humans are viewed as emergent then clearly prior emergence plays a causal role. As human agency is involved to at least some extent in all three emergent relations under consideration, then subjectivity is a causal factor in all cases, although some characteristics may be incidental.

In the planned case, manufacture and design are generators of the machine characteristics and functionality rather than self-organisation. Again, analysis of the unplanned case depends on perspective. It could be argued that it is purely down to human agency – i.e. observation; however, I would argue that it is also partly a result of self-organisation, as the general system conditions need to arise before the observation of the potential new function for the machine can be recognised. These conditions arise from uncoordinated actions within the wider emergence system and environment and are not deliberately created with the intent of serving the function.

As humans are part of the system, epistemological factors are highly likely to play a causal role. Clearly, in all three emergents under discussion, observation – which in this case equates to subjectivity – plays at least an indirect a causal role. Further, both the macro-level characteristics of the machine and its functionality are based on an understanding of engineering and socio-technical systems. Thus, reasoning, I would argue, is also a contributing factor.

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[62] It should be noted that such cellular automata are very slow at computation and so are not used in practice.

As there may be unplanned characteristics or functionality associated with a machine, a different resolution may expose new generators. Further a wider scope may also affect perception of generators of unplanned functionality. But new generators identified are unlikely to be of a different type from those identified above.

A summary of the above analysis of the generators of the function of a machine is presented in Table 7-11 below.

Generators		**Characteristics of a machine**	**Planned function of a machine**	**Unplanned function of a machine**
Generators of macro-level properties	*Component constraints*	Yes	Yes	Yes
	Macro constraints	Yes	Yes	No
	Relational constraints	No	Yes	Yes
Construction	*Self-organisation*	No	No	Yes
	Manufacture	Yes	Yes	Yes
	Design	Yes	Yes	No
	Prior emergence	(Possibly)	Yes	Yes
	Subjectivity	Probably	Yes	Yes
Epistemo -logical generators	*Observation*	Probably	Yes	Yes
	Reasoning	Probably	Yes	Yes
Epistemo -logical influences	*Scope*	No	No	Possibly (not type)
	Resolution	Possibly (not type)	No	Possibly (not type)

Table 7-11: Analysis of the generators of the emergence of the function of machine

Causal powers associated with the functionality of a machine

Whether the macro-level entities – the machine or its functionality – have macro-level causal powers is a question of perspective. A machine may arguably be viewed as affecting other macro-level objects as it carries out tasks, either with or without human intervention. This is, in general, reducible to a product of its component parts and human agency. The case of functionality is much more difficult to assess. For example, as functionality is really predominately a conceptualisation of the tasks that a machine might carry out, can it really be said to have causal powers? Further, how do we identify the macro-level at which this functionality might act? Arguably ideas can lead to other ideas. For example, it could be argued that the functionality of computers gave rise to the Information Society, or the functionality of the printing press gave rise to the scientific revolution. However, I would suggest this apparent power is actually the benefit of hindsight and the 'level' at which analysis of such events takes place.

Neither the macro-level characteristics of a machine nor its functionality can be said to downwardly influence their component parts. Although in the latter case the caveat must be that it depends on what the component parts are assumed to be. For example, conceptualisations can limit people's points of view and behaviour. However, this is probably true for any psychological emergence and is discussed more in subsection 7.1(g). It is therefore ignored here.

A summary of the analysis of the causal powers associated with the functionality of a machine is presented in Table 7-12 below.

Causal power		**Characteristics of a machine**	**Planned function of a machine**	**Unplanned function of a machine**
Macro-level		Product	(Possibly product)	(Possibly product)
	Scope	No	No	No
	Resolution	No	(Level of analysis)	(Level of analysis)
Downward causation		No	No	No
	Scope	No	No	No
	Resolution	No	No	No

Table 7-12: Analysis the of causal powers of the function of a machine

Conclusions regarding the emergence associated with the functionality of a machine

Consideration of the emergence associated with the functionality of a machine highlights four important points. Firstly, functionality is a relational property. Thus again, the consideration of component emergents within the overall emergence system associated with the functionality of a machine helps clarify relationships and causal factors. Secondly, the key difference between the emergence of planned and unplanned functionality is that macro constraints do not directly drive unplanned functionality; rather, human agency within a wider scope is key. Thirdly, as human agency is central to the emergence of functionality, this adds layers of complexity to the emergence system. Thus, while at first sight, consideration of the emergence of functionality might appear trivial, it is in fact complex and an 'interesting case'. For example, human agency might itself be argued as an emergent characteristic of human biology. However, I would argue that it is best considered as an individual component of the emergence system rather than in terms of its constituent parts as full reduction is not possible in practice. Finally, understanding functionality requires consideration of the processes involved in attaining the function of a machine. Thus, I would argue, emergence cannot be understood purely in terms of 'things', understanding of processes, be they epistemological or physical, is also required.

(e) World Wide Web

The emergence system and emergence relation(s) associated with the World Wide Web

The World Wide Web (Web) is a complex and highly structured global information network, the likes of which has never been seen before. If the emergence of this radically novel human artefact is to be fully understood, how it is constituted, how it came into existence and its causal powers need to be assessed.

Technically, the Web consists of a set of interlinked hypertext documents which are accessed through web browsers and servers over the Internet. This network of hypertext documents has properties which are not contained in the individual documents. For example, it has a distinctive graph structure (Broder et al. 2000) where the connectivity of hypertext documents satisfies power law relations (Albert 1999, Broder et al. 2000) and constitutes a small world network (Adamic 1999). Thus, these properties are global properties of the complex network of interrelated documents which forms the Web and not of the individual documents. This suggests that the structural properties of the network are a form of emergence, where the emergence relation is the relation between the structural properties of the global repository of hypertext documents and the individual documents.

This view of the web as just a collection of interrelated documents which have network (macro-level) properties is a considerable oversimplification. It is a radically novel human artefact which is viewed as a holistic entity and has significantly contributed to changing our everyday lives. From this perspective, the Web is a socio-technical product which has arisen from the agency of humans and the availability of technology to support it[63]. Thus, the emergent relation might reasonably be viewed as that between the global information network and the people, technology and hypertext documents which shape it. Inclusion of people and technology, I would argue, is vital as neither the initial development of the Web nor its subsequent structure can be fully understood without reference to both people and technology.

Thus, two perspectives of emergence associated with the Web can be identified – the emergence of macro-level network properties from the interconnection of hypertext documents and the emergence of the Web from human agency, hypertext documents and technology. These are captured in the emergence system outlined in. Figure 7-5 below.

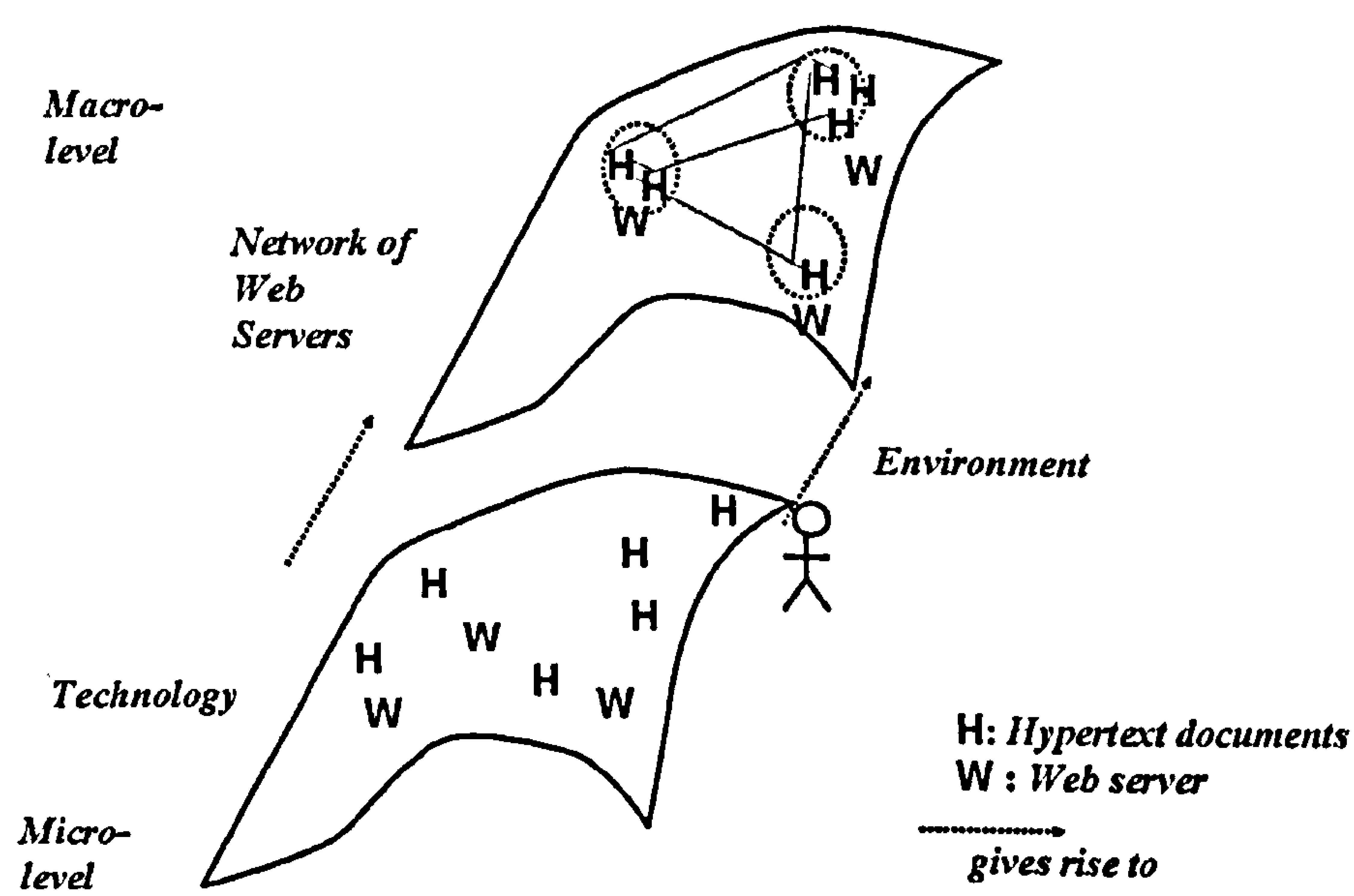

Figure 7-5: Overview of the emergence system and emergence relations associated with the Web

As Figure 7-5 above attempts to illustrate, these two examples of emergence are not distinct; rather they arise out of different perspectives as to what emergence is and what should be considered as contributing to its physical determination. Thus, epistemological factors will clearly influence interpretations of the Web as an emergent phenomenon.

The emergence of the Web from the interaction of people and technology and the emergence of its structure from the interconnectivity of hypertext documents are both considered in further detail in the following subsections.

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[63] Technological availability is of course also down to human agency.

Meta-relational properties

The radical novelty of the Web would suggest that it was a surprise. However, certain concepts central to the Web had been envisaged over the years. For example, Vannevar Bush (1945) conceptualised a flexible personal information store – the Memex – accessible from anywhere. Additionally, Nelson, who is credited with inventing hypertext in the mid 1960s, developed the concept of a non-linearly navigable "docuverse", where all data is stored once without deletion and all information is accessible by a link from any location (Nelson 1981). So, the emergence of the Web phenomenon, to information specialists at least, was not a total surprise although the speed of uptake was not anticipated. On the other hand, the structural characteristics of the Web were totally unexpected.

While evolving understanding of information and computation are increasing the predictability of many aspects of the Web, its exact shape and speed of uptake depend both on human factors and technology availability. This makes it predictable in theory only, as it is a result of non-linear interactions. Further, as our understanding of complex network dynamics increases through work such as Barabasi and Albert (1999) and Adamic (1999), much of this ongoing evolution of the Web structure is increasingly predictable, as disparate complex networks appear to share characteristics depending on their node connectivity rules.

Explanation, in the form of scientific understanding of the Web, is still in its early days as the new Web Science Research Initiative[64] illustrates (Berners-Lee et al. 2006). As the multiple disciplines involved in this initiative – ranging from computer science to economics and sociology – illustrate, understanding the Web requires a socio-cultural as well as a technological perspective. Thus, explanation is likely to require reference to macro-level features such as culture and markets and therefore is not wholly reducible to micro-level features such as the virtual location of individual documents. There is no reason to suppose the explanation is not reducible in principle to a complex product of the many constituent parts which contribute to the Web. However, given the complexity and human agency involved, this is unlikely to be reducible in practice, no matter how wide a scope of investigation is adopted or what future theoretical advances occur.

The meta-relational properties associated with the emergence of the global phenomenon of the Web and its structure are summarised in Table 7-13 below.

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[64] http://www.webscience.org/

Meta-relational property		Web	Structure of the Web
Surprise		Possibly	Yes
Predictability of emergent		In principle	In principle
	Scope	No	No
	Resolution	No	Possibly
Reducibility of explanation		Complex product	Complex product
	Scope	No	No
	Resolution	No	No

Table 7-13: Analysis of meta-relational properties associated with the emergence of the Web

Generators of the World Wide Web

The Web is essentially a human artefact and therefore manufactured. Its development can be traced back to 1989 and a CERN project, led by Sir Tim Berners-Lee and Robert Cailliau, designed to help support CERN scientists in sharing information (Cailliau 1995). The project itself was developed from independent proposals by Berners-Lee and Cailliau, who chose to combine their proposals to gain CERN support. So from the beginning, constraints imposed by the needs of individuals to collaborate and available funding – i.e. macro-level 'system' constraints – were at the core of the development of the Web.

While the initial rationale for development was problem-based, the availability of technology has been equally important to the development of the global phenomenon that is the Web. It was the connection of CERN physicists to the Internet which enabled the spread first within that global community and then to the wider Internet as the advantages of the Web were observed. Equally, this spread could not have occurred without the spread of the Internet, the increasing availability of desktop computers or early web browsers. So, social interaction which informed design and implementation, and technological availability – i.e. component constraints of the socio-technical system that construes the Web – play a prominent causal role.

The adoption of the Web by specific communities has also been instrumental. For example, in order to keep abreast of the latest developments, it became increasingly necessary for physicists to be connected to the growing Web. This meant higher education and research institutes had to connect to the web, further increasing its geographical spread. This then led, through feedback, to further diffusion within these institutions. So, observation, reasoning and ongoing emergence – the uptake by specific groups – also significantly contributed to the development of the Web. As humans are an integral part of the emergence system, observation and human agency indicates subjectivity within the system.

Neither the Web nor its structure directly arises out of the relationship between the Web and external objects and therefore relational constraints are not a core causal factor.

While there has been central development of protocols and web standards through the World Wide Web Consortium (W3C), there has been no central design of its uptake or shape. Rather this has arisen through individual choices to implement Web sites and link individual documents and so self-organisation has played a significant role in the generation of the Web and its structure. What the W3C and Berners-Lee, in particular, have done is design the right conditions for this self-organisation to flourish. For example, the initial decision by CERN to make the web technologies publicly available and availability of the NCSA's Mosaic browser are key turning points in the emergence of the global information structure[65].

The physical instantiation of the novel global information repository that is the Web and its structure are generated by hyperlinks – component constraints – between documents. The decision to link documents is however made by humans based on a wish to link to other relevant documents and key sites such as Google and advertising sites to gain revenue. Thus, observation and reasoning builds on the ongoing emergence to further develop the physical structure. However, as the micro-level components being considered in this case are the hypertext documents, there is no subjectivity inherent in their relations. Likewise, given this context prior emergence is not really a factor in the structure.

As the Web evolves key sites such as Google begin to act as attractors which are in effect macro constraints to the structure.

The actual structure of the Web is again manufactured (constructed) through individual's decisions to link documents – i.e. an aggregation of intentional actions. In this case there is no real claim to central design; rather the structure that emerges is a result of individual choices, which are themselves constrained by the existing Web structure and socio-economic factors such as competitive advantage, altruism or self-promotion.

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[65] http://www.livinginternet.com/w/wi.htm

The novelty of the Web and its structure exist independent of theory and are global properties of people and technology in the former and linked hypertext documents in the latter. So they are not purely epistemological in nature. However, as human agency plays a considerable role, observation and reasoning are clearly significant factors in the emergence of the Web and its structure. Further, the scope of consideration clearly plays a role in the identification of generators of the structure of the Web as the above discussion on subjectivity and prior emergence indicates

A summary of the analysis of the synchronic and diachronic generators of the Web is presented in Table 7-14 below.

Generators		**Web**	**Structure of the Web**
Generators of macro-level properties	*Component constraints*	Yes	Yes
	Macro constraints	Yes	(Yes)
	Relational constraints	No	No
Construction	*Self-organisation*	Yes	Yes
	Manufacture	Yes	Yes
	Design	Yes	No
	Prior emergence	Yes	(No)
	Subjectivity	Yes	(No)
Epistemo -logical generators	*Observation*	Yes	Yes
	Reasoning	Yes	Yes
Epistemo -logical influences	*Scope*	No	Yes
	Resolution	No	No

Table 7-14: Analysis of generators of the emergence of the Web and its structure

Causal powers associated with the Web

The Web as a phenomenon does appear to have an impact at an economic or societal level. For example, a Web presence is increasingly essential for any commercial organisation, be it for eCommerce or for marketing purposes. Additionally, its influence is changing the way we participate in Government through eGovernment schemes such as electronic voting in

Estonia (InformationWeek 2007). While it might be argued that these causal powers are really micro-level, the push towards web-based commerce has arisen from the global nature of the Web and so the causal power of the Web cannot be understood in terms of individual people and documents alone. Thus, I would argue, the Web may be viewed as having macro-level causal powers, where these powers are reducible, in principle only, to a complex product of the properties of its component parts. The multiple layers of emergence that give rise to culture, politics or the economy make this irreducible in practice. Adoption of a different scope or new theoretical understanding is, I argue, unlikely to increase reducibility.

The actual structural properties of the Web may also be said to have causal powers. For example its global structure enables the 'long tail effect' where, by greatly lowering search costs, Web-based markets can facilitate substantial increases in the collective share of niche products, thus creating a longer tail in the distribution of sales (Brynjolfsson et al. 2006). This power is explicable as a product of the overall link structure.

I would argue adoption of a different scope or new theoretical understanding is unlikely to change the reducibility of these apparent macro-level powers.

In both the emergence of the global phenomenon of the Web and its structure, downward causation is in evidence. For example, the advent of social networking sites is increasingly changing how we communicate with each other and spend our leisure time. It is the existence of the Web itself, I would argue, that has driven the development of these new Web 2.0 technologies, which are in turn radically changing the Web. As there is an element of feedback from the existence of the Web and what it facilitates to the development of the new technologies, I would argue this falls into the 'constraining' type of downward causation identified in Chapter 6, Table 6-3, as it cannot really be said to be a result of attractor dynamics only.

In the case of the structure of the Web, new Web documents are preferentially attached by linking to existing hubs such as Google or Wikipedia or content-related documents rather than a random site (Barabasi and Albert 1999). This preferential attachment further shapes the complex network of hypertext documents – i.e. the shape of the Web dictates the attraction of new links.

Again, I would argue, adoption of a different scope or new theoretical understanding are unlikely to change the downward causation relating to the Web or its structure.

Table 7-15 below summarises the above analysis of the causal powers of the Web.

Causal power	**The Web**	**Structure of the Web**
Macro-level	Complex product	Product
Scope	No	No
Resolution	No	No
Downward causation	'Constraining'	Attractor reducible
Scope	No	No
Resolution	No	No

Table 7-15: Analysis of causal powers of the global Web and its structure

Conclusions regarding the emergence associated with World Wide Web

Examination of the emergence associated with the Web exemplifies how the complexities of people and technology make it difficult to understand some forms of emergence. In this example, the emergents are the Web itself and its structural properties. The emergents, as Figure 7-5 above illustrates, are physically instantiated through the individual hypertext documents. But, as the Web is a human artefact and therefore constructed, the emergence cannot be understood simply in terms of a network of interlinked hypertext documents. Social considerations such as culture and economic advantage (game theoretic issues) affect the structure, making explanation of the global structural properties weakly reducible to the documents, complex network theory and social theory, provided sufficiently wide scope is adopted.

However, the picture is complicated for three reasons. Firstly, while the Web is an engineered space, where its macro-level features are driven by human agency and interaction, which in turn are governed by macro-level socio-economic constraints (Berners-Lee et al. 2006). This means that unlike the case of the functionality of a machine, the Web itself is continually evolving due to both micro-level and macro-level factors. Secondly, the emergence system is part of a co-evolving socio-technical system. This makes identification of causal factors particularly difficult. Finally, as this evolution is ongoing and we are a central part of it, it is not clear whether we have identified the full extent of the emergent properties of causal powers of the Web.

(f) Life

The emergence system and emergence relation(s) associated with life

As discussed in Chapter 2, life has been one of the main drivers of the investigation of emergence. Emergence of life can be viewed from two perspectives: (i) abiogenesis – the emergence of the first life on Earth around 3.8 billion years ago, which radically changed the abiotic Earth and (ii) the continual emergence of the biosphere from underlying physical/chemical layers. The former emergence captures the appearance of a radically novel phenomenon and the latter, to a large extent, captures the continued instantiation of that novel phenomenon. While these might seem to represent a diachronic, synchronic perspective respectively, both emergences demand a diachronic perspective as metabolism and reproduction – the essence of life[66] – are dynamical processes as opposed to properties. The main different between these two emergents is differing environmental factors. In the ongoing emergence of life, the autocatalytical biological processes which ensure cell development are already in existence, whereas in the case of proto-cell development in abiogenesis, suitable conditions needed to be present for the autocatalytical processes to first arise. Figure 7-6 below attempts to capture these differences in the emergence system associated with the emergence of life.

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[66] Establishing the emergent relation in these cases is difficult given there is as yet no universally agreed definition of life (Emmeche 1997). For simplicity, life is considered to be based on organic entities which engage in metabolism and reproduction. As the original interest from an emergence perspective was the apparent emergence of the biological level from the physical/chemical, this analysis concentrates on biological life on Earth, rather than a wider definition which could include extra terrestrial and artificial life. Even this starting point does not lead to a simple definition of life. For example, typical intuitive assumptions that life consists of metabolism and reproduction, exclude viruses.

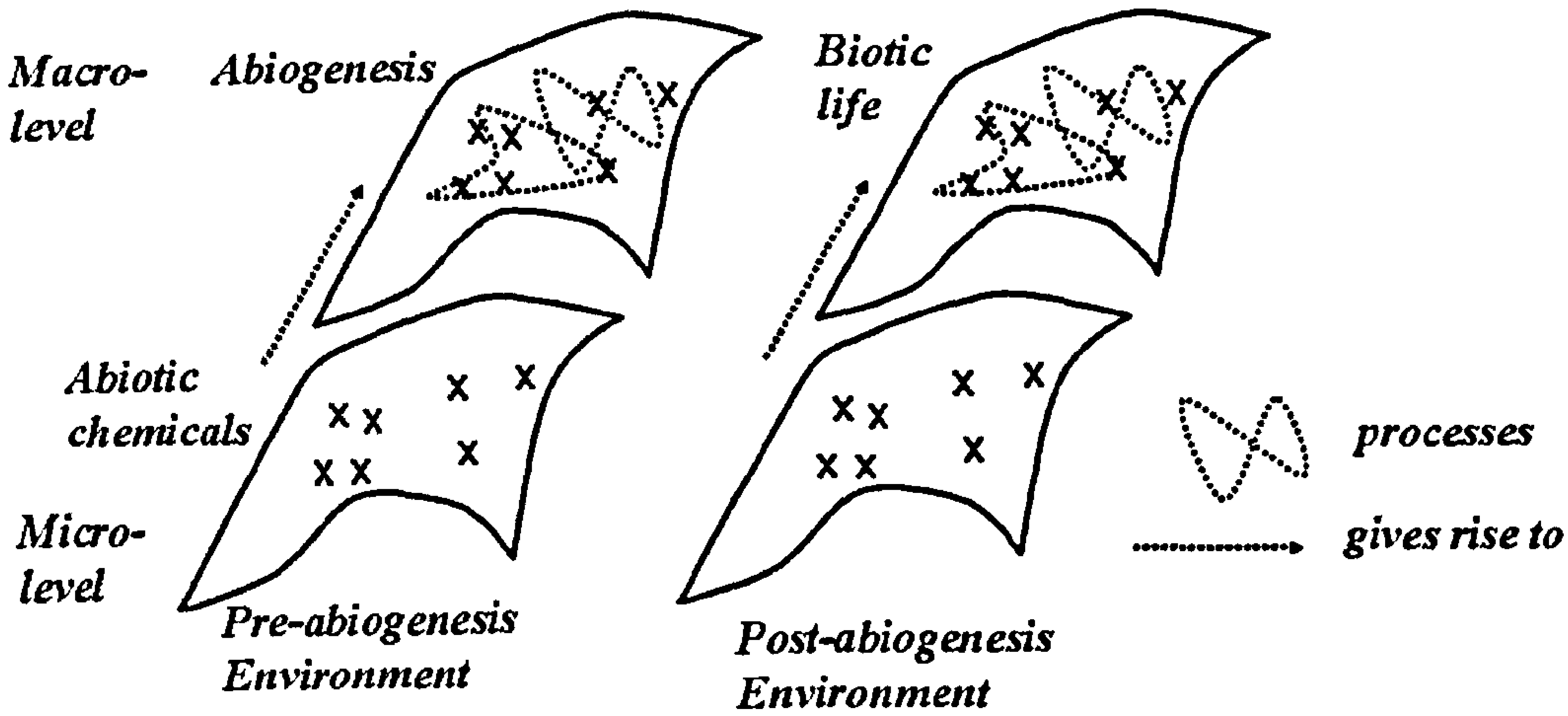

Figure 7-6: Overview of the emergence system and emergence relations associated with life

As Figure 7-6 above captures, in both abiogenesis and the continual emergence of life the emergence relation is between chemicals and metabolic and reproduction-based life. These two emergence relations are examined in further detail in the following subsections. As the exact mechanisms of abiogenesis are still open to question, this account is based on Martin & Russell (2002), Russell & Hall (1997) and Russell & Hall (2000). Alternative views on the specifics, all of which have significant criticisms, can be found in Miller (1953), Cairns-Smith (1985) and Huber & Wächterhäuser (1998). These alternative views differ in timing and environmental conditions rather than the fact that specific emergent features or processes must have occurred and therefore do not significantly affect the analysis. There are no epistemological factors represented in Figure 7-6, as life is unlikely to have epistemological causes since it existed before there were humans there to observe and understand it.

Meta-relational properties of the emergence of life

Abiogenesis cannot be said to have been a surprise as there was no-one to observe its emergence. The ongoing emergence of biological life cannot truly be said to be a surprise, as it is part of our every day experience and so it is not solely phenomenological in nature. Rather conceptualisation as emergence appears to arise from our need to apply different theories to understand life as opposed to its chemical substrate.

The predictability of the emergence of abiogenesis is difficult to assess as we do not yet fully understand how life arose. Many of the current proposals for the beginning of life are centred on the assumption that the precursor to life was the development of simple organic monomers from abiotic chemicals (e.g. Miller (1953), Huber (1998), Russell (1997)). This is thought to have arisen when the required conditions developed by chance. For example, the Urey-Miller laboratory experiments showed an abiotic 'soup' of chemicals such as iron, sulphur, carbon dioxide and water can spontaneously form into organic monomers (Miller 1953). As the abiotic Earth can be thought of as a nonlinear system, this 'chance' is likely to be the result of non-linear dynamics. Additionally, while every day emergence of the biosphere from the physical/ chemical level is clearly highly (statistically) predictable, it is in effect the result of attractor dynamics of a highly complex system (Kauffman 2000) and therefore non-linear in nature. Thus, the predictability of both abiogenesis and ongoing biological life might reasonably be classified as 'in principle'. However, improved theorising may lead to better understanding about the mechanisms, requiring a change to predictability.

Explanation of the emergence of abiogenesis is generally attempted from a reductionist or weakly emergent perspective. For example, Russell and Hall (1997) consider the emergence of life from a complex systems perspective[67], where specific environmental conditions – hot undersea vents – first permit chemical pathways to develop which support autocatalytic reproduction of simple organic components. This leads over time to construction and reproduction of more complex organic molecules which mimic proto anabolisation and catabolisation, which are required for metabolism. This, combined with an environmental structure – iron monosulphide bubbles – which aids compartmentalised cell development, they suggest may lead to the emergence of life (Martin and M.J. 2002, Russell and Hall 2000, Russell and Hall 1997). So while there is no generally accepted theory of abiogenesis, an explanation based on a complex product of component chemicals, environmental conditions and the multiple layers of change brought about through dynamical interactions over time appears plausible.

As became evident in the review of Chapter 2, the explainability of biological life through its chemical component parts alone is highly debated. Even at the cellular level, life requires a non-linear explanation, based on the interplay between metabolism and reproduction. For example, metabolism is responsible for making DNA which contains the genetic instructions used in reproduction of metabolism mechanisms. As evidenced by the systems biology movement, many scientists believe that life could be 'explained' by a complex product of the multiple layers of interaction between chemicals and the environment. Given the complexity

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[67] E.g. Russell and Hall (1997, p383) draw comparison of the abiotic ocean floor and vents and Prigogine's dissipative structures in far from equilibrium conditions stating, "this environment is ripe for the emergence of the most complex form of dissipative structures, life".

of biological systems, it is unlikely that changing scope or theory will increase the reducibility of explanation.

The meta-relational properties of the emergence of life are summarised in Table 7-16 below.

Meta-relational property	**Abiogenesis**	**Biological life**
Surprise	No	No
Predictability of emergent	In principle	In principle
Scope	No	No
Resolution	Possibly	Possibly
Reducibility of explanation	Complex product	Complex product
Scope	No	No
Resolution	No	No

Table 7-16: Analysis of meta-relational properties associated with the emergence of life

Generators of Life

Both the emergence of the first life on Earth and its subsequent persistence have constraints between chemical components – that is chemical bonding and autocatalytic processes – at their core. Without these component level constraints, life would not exist. For example, for complex organic molecules such as proteins, ribosome such as RNA and amino acids had to be formed before life could exist. And DNA which is a long organic polymer made up of nucleotides bonded to a backbone of sugars and phosphates is essential to the generation – (re)production – of biological life today.

Abiogenesis first required a number of intermediate steps such as chemical pathways, proto-anabolisation and catabolisation and cellular membrane. These features acted as macro-level constraints, constraining the behaviour of the lower level components. For example, according to Russell and Hall (1997) iron-sulphide bubbles in deep sea vents provided a scaffolding for proto-cell development. This also means that life on Earth is generated, in part at least, by prior emergence. This reliance on prior emergence is still found in biological life today. For example, while iron-sulphide bubbles or other intermediate structures are no longer required to provide scaffolding for life, a selectively permeable cellular membrane which encloses the biochemical pathways of metabolism and reproduction is still required. This membrane arises from chemical pathways – macro constraints – which generate amphipathic lipids which have the unusual characteristic that their heads are hydrophilic, being attracted to water, while the bulk of their structure is hydrophobic. Thus, they spontaneously arrange so that the hydrophobic 'tail' regions are shielded from the surrounding fluid, causing the more hydrophilic 'head' regions to associate with the cytosolic and extracellular faces of the resulting bilayer. This forms an extremely thin continuous, spherical lipid bilayer which encapsulates the components of the cell.

Equally, macro constraints play an important role both in the initial and subsequent evolution of life. For example, in both cases an input of energy is required for life to exist and slight changes in the alkalinity of the environment can easily lead to the cessation of life. Abiogenesis especially required considerable macro constraints, be it Russell et al's hot undersea vents and iron monosulphide bubbles or Cairns-Smiths' (1985) clay. Relational constraints are also core to both abiogenesis and the ongoing emergence of life as there are constraints between 'compound objects' and not just micro-level components. For example, cellular reproduction relies on DNA. DNA is a long term memory containing information which is used to construct other components of cells.

Consider the role of DNA in biological systems. While DNA serves a function at the biological level, the DNA itself is a chemical, which obeys chemical laws – i.e. micro-level rules. As Silberstein (2002, p100) observes, this gives rise to "multilevel descriptions of causal mechanisms that mix different levels of aggregation from cell to organ back to molecule". Thus, multiple 'levels' of causation must be examined if emergents are to be fully understood.

What distinguishes life from purely physical-level phenomena is the role of subjectivity. Within the biosphere, one biological component may use another. Indeed this is a necessity for the emergence as the interdependence of metabolism and reproduction illustrates. This subjectivity is not epistemic in nature as it is not a result of our knowledge; rather it is intrinsic to the biological level.

Assuming a non-'intelligent design' perspective and that life on Earth was not externally seeded then its development must be due to self-organisation, rather than design or manufacture. Additionally, as the likes of Kauffman (1993) have shown, self-organisation continues to be at the core of the persistence and continued evolution of life.

As life exists independent of our observation or conceptualisation, it is not generated by epistemological factors. Further, increased scope or resolution is unlikely to change the types of generators, although specific mechanisms of abiogenesis may become clearer through improved theoretical understanding.

A summary of the analysis of the synchronic and diachronic generators of life is presented in Table 7-17 below.

Generators		Abiogenesis	Biological life
Generators of macro-level properties	*Component constraints*	Yes	Yes
	Macro constraints	Yes	Yes
	Relational constraints	Yes	Yes
Construction	*Self-organisation*	Yes	Yes
	Manufacture	No	No
	Design	No	No
	Prior emergence	Yes	Yes
	Subjectivity	Yes	Yes
Epistemo-logical generators	*Observation*	No	No
	Reasoning	No	No
Epistemo-logical influences	*Scope*	No	No
	Resolution	(Yes)	No

Table 7-17: Analysis of generators of the emergence of life

Causal powers associated with life

Since abiogenesis, biological life has continued to spread and develop. Whether it has macro-level causal powers is again a question of perspective. Abiogenesis created a brand new 'level' and so it is questionable whether a new level can have causal powers at that level. The individual components of the level – the various components and processes which developed through abiogenesis and the continued evolution of life – do clearly interact within the biosphere and this interaction is more sophisticated than simple chemical interactions. For example, biological cells take part in biological level rules of metabolism and reproduction. Thus, I would argue, it is reasonable to view the components of life as having a form of biological level causal powers. It is generally accepted that this behaviour is non-simply reducible to the properties and behaviour of the abiotic chemical components.

Thus, the macro-level causal powers associated with biological life may be considered to be a product of its micro-level component parts, albeit a highly complex product. Adoption of a wider scope or new theoretical understanding is, I would argue, unlikely to increase reducibility.

Downward causation appears inherent in biological life. For example, the higher-level processes of metabolism and reproduction may be viewed as constraining the structure and behaviour of the individual abiotic chemical components. This, I would argue, is independent of scope and is unlikely to be altered by new theoretical understanding.

Table 7-18 below summarises the above analysis of the causal powers of life.

Causal power		**Abiogenesis**[68]	**Biological life**
Macro-level		Complex Product	Complex Product
	Scope	No	No
	Resolution	No	No
Downward causation		Constraining	Constraining
	Scope	No	No
	Resolution	No	No

Table 7-18: Summary of the analysis of causal powers of life

Conclusions regarding the emergence associate with life

The emergence of life from the Earth's abiotic environment is perhaps the prime example of the power of emergence; the earth was irrevocably changed, opening the way for not only a new 'level' but also much variety and further emergence.

As the initial emergence – abiogenesis – led to a whole new biological level, both abiogenesis and the continual emergence of life from abiotic chemicals were examined. Interestingly, while abiogenesis and the ongoing emergence of life have different physical components, the preceding analysis illustrates that the key characteristics associate with

[68] As discussed above it does not really make sense to discuss the causal powers of Abiogenesis *per se*; however it is included for completeness and is considered identical to ongoing life.

emergence are the same in both cases. Further, as processes form a key part of both emergences, they need to be examined within a dynamic context.

The analysis of the emergence associated with life is difficult for two reasons. Firstly, life itself is not a distinct, albeit, macro-level entity. Rather our concept of life arises from a group of processes and biological-level entities which emerge from chemical level components and their dynamics. It is thus difficult to establish what exactly the emergence relation is and what types of constraints play a causal role. Part of the issue, I would suggest, is that we deal in abstractions, discussing life as if it is a well-defined entity, which closer examination indicates it is not. Thus, while the preceding analysis shows that physical entities and processes which give rise to the biosphere have no epistemological causal factors our perception of life as an entity can increase the difficulties in fully understanding it. Secondly, life is associated with the emergence of the biosphere – a hierarchical level – and not just a higher-level entity. While individual entities or processes within the biosphere might reasonably be viewed as possessing macro-level causal powers, considering causal powers of the hierarchical level itself does not make sense.

(g) Mind

The emergence system and emergence relation(s) associated with mind

The difficulties in understanding mind, like life, have been one of the main drivers for the conceptualisation of emergence. Similarly, like life, it is unclear exactly what the mind is. For some it is what the brain 'does' (Bownds 1999) and others it is perceived as a collection of properties or behaviour which include consciousness, belief, desire, perception, reasoning, emotions and self-awareness. This is further complicated by the fact that the minds of animals possess different properties from that of humans. For example, while most mammals appear to possess memory and consciousness, the so called metacognitive properties such as reasoning and self-awareness[69] appear unique to humans. It is these metacognitive properties which encapsulate our conscious experience and it is how these distinctive mental properties can arise out of non-sentient physical components of the brain that has led them to be considered as emergent (Kim 1998). This analysis will therefore focus on such meta-cognitive mental properties.

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[69] Some higher-level primates do show a degree of self-identity in mirror tests; however this does not imply that they can reason about themselves or others as cognitive beings – key human capabilities.

Figure 7-7 below captures this in an outline of the emergence system associated with the emergence of mind.

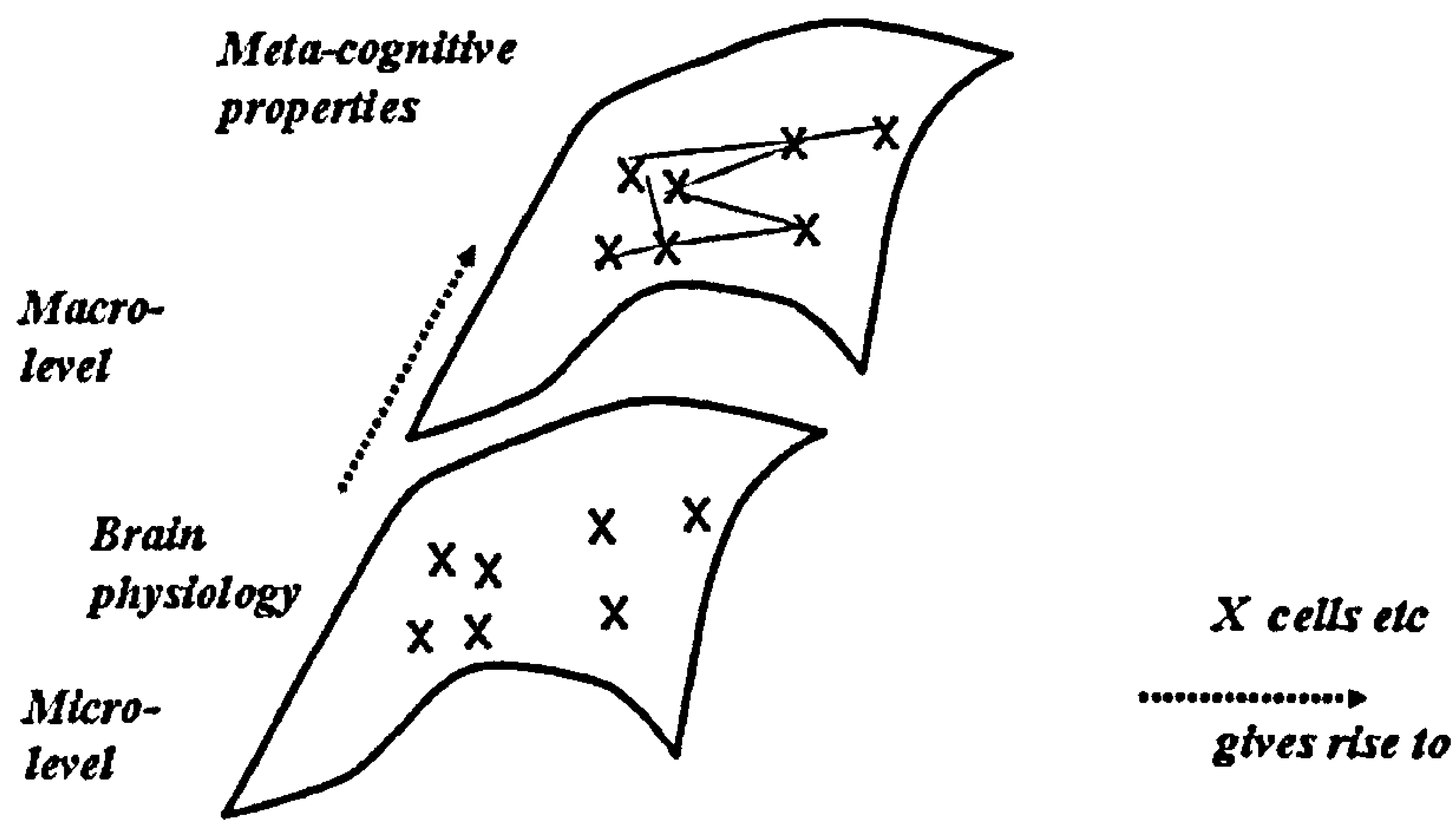

Figure 7-7: Overview of the emergence system and emergence relations associated with mind

This emergence relation is examined in more detail in the following sections. While it is increasingly recognised that to fully understand the mind a dynamic perspective must be adopted (Collier and Muller 1998, Kim 1998, O'Connor and Wong 2005), the majority of approaches are concerned with the continual emergence of mind rather than its first appearance. For simplicity, the same approach is adopted here.

Meta-relational properties of the meta-cognitive properties associated with mind

Clearly the meta-cognitive properties of mind cannot be surprising as surprise is phenomenological and thus depends on these properties existing. Nor are they in general predictable except in a purely statistical sense through experience. As there is no theory or dynamics which can be used to predict meta-cognitive properties they are generally considered unpredictable at present, although there is an argument that they might be predictable in principle as they are a result of non-linear interactions between the components of the brain. While improved theoretical understanding may make this possible, a wider scope is not expected to make a difference.

Currently there is no explanation of metacognitive properties in terms of the components of the physical brain. As the review of Chapter 2, subsection 2.3.1 highlighted, this irreducibility is often viewed as strong – i.e. even if we knew everything there is to know about the physical properties of the brain we could never explain the metacognitive properties in terms of these properties and their interactions. It is unclear where this irreducibility arises from. For example, it could be that it is a limit of our cognitive/information processing abilities and a more intelligent being might be able to fully explain our meta-cognitive properties by reference to the physical components of the brain and their interactions. On the other hand, new understanding may make it reducible to a complex product of the properties and interactions of the physical components or it might indeed be intrinsically irreducible. Thus, resolution is a factor but a wider scope is not expected to increase the reducibility of explanation.

The meta-relational properties of the mind are summarised in Table 7-19 below.

Meta-relational property	**Meta-cognitive properties**
Surprise	No
Predictability of emergent	Unpredictable/In principle
Scope	No
Resolution	Possibly
Reducibility of explanation	Irreducible/Complex Product
Scope	No
Resolution	Possibly

Table 7-19: Summary of the analysis of meta-relational properties associated with the emergence of mind

Generators of the meta-cognitive properties associated with mind

The complexity of the physical brain and the current level of scientific understanding make identifying the generators of the meta-cognitive properties of mind difficult. However, it seems safe to say that component level constraints such as the interlinkage of neurons play a part. The meta-cognitive properties are thought to arise out of a number of 'layers of prior emergence. For example, emergent features of the physical base such as the memory and the ability to access it are thought to be essential to meta-cognitive properties as we cannot reason about anything unless we can access its memory. This suggests that relational constraints between various sets of meta-components of the brain also play a causal role. It is less clear whether macro-level constraints play a role. The best that can be said is that this is an open question.

Despite the central 'I' associated with meta-cognitive properties, evidence shows that there is no central control area within the physical brain and so these properties are a result of decentralised self-organisation rather than central design or control. The role of subjectivity is also difficult to establish. It clearly exists as the role of different physical brain areas in memory illustrates, but whether this is a necessary condition for meta-cognition is unclear.

Analysis of epistemological generators on the emergence of mind is particularly problematic, as we need to make recourse to the metacognitive properties themselves to do so. Observation in the sense of self-awareness is intrinsic to the meta-cognitive properties of mind but whether this is a casual influence rather than an effect is questionable. Reasoning is itself a meta-cognitive property and therefore it would be inappropriate to consider it as a generator. Increased scope is unlikely to lead to new generators as scientists are already considering the impact of the environment on the development of meta-cognitive properties. For example, evidence from animal brains and hominid fossils strongly suggests that mental properties evolved over time as a result of environmental stimuli and natural selection. However, we should be open to the fact that new theoretical developments might identify new generators.

A summary of the analysis of the generators of the meta-cognitive properties of mind is presented in Table 7-20 below.

Generators		Metacognitive properties
Generators of macro-level properties	*Component constraints*	Yes
	Macro constraints	Unknown
	Relational constraints	Yes
Construction	*Self-organisation*	Yes
	Manufacture	No
	Design	No
	Prior emergence	Yes
	Subjectivity	Probably
Epistemo-logical generators	*Observation*	Unknown
	Reasoning	N/A
Epistemo-logical influences	*Scope*	No
	Resolution	Possibly

Table 7-20: Analysis of generators of the emergence of mind

Causal powers analysis of the meta-cognitive properties associated with mind

The power of the mind to exert causal influence over the physical is at the heart of (perceived) human agency. The attempt to explain how the mind exerts this causal influence has been one of the main preoccupations within the philosophy of mind over the last 30 years. Kim (1998) offers two reasons to support mental causation: (i) the human ability to reason and develop new knowledge and (ii) human agency which affects the physical world. The former suggests causal interactions at the psychological level – that is macro-level causal power. While these causal powers are irreducible at present, it is much debated whether new understanding might make this reducible in principle at least.

Downward causation relating to meta-cognitive properties is particularly difficult to examine. While we perceive that it is our meta-cognitive decisions – i.e. our mental decision – that 'causes' a limb to move, it must be noted that our perceptions are only that – perceptions and not objective reality. We cannot independently determine which occurs first – our mental wish to move a limb or a set of physical stimuli which cause both our limb to move and us to apparently decide to move the limb. Indeed, recent investigations which monitor the brain activity that occurs when an external stimulus is provided suggests, in certain cases at least, that micro-level activity may occur prior to our macro-level decisions. Thus, the best that can be said is that the apparent irreducibility of downward causation associated with meta-cognitive properties may a result of our current understanding and scope of analysis and thus epistemological.

Table 7-21 below summarises the above analysis of the causal powers of the meta-cognitive properties associated with mind.

Causal power		**Meta-cognitive properties**
Macro-level		Currently irreducible
	Scope	No
	Resolution	Possibly
Downward causation		Currently irreducible
	Scope	Possibly
	Resolution	Possibly

Table 7-21: Summary of the analysis of causal powers of meta-cognitive properties

Conclusions regarding the emergence associated with mind

As the preceding analysis shows, the rationale for considering meta-cognitive properties of the human mind as emergent is to explain their apparently irreducible causal powers – the ability to reason and to decide to do something being prime examples. The emergence is in general perceived as strongly irreducible in nature, where the meta-cognitive properties or behaviour cannot be explained even in principle through the micro-level properties or 'states' of the brain.

The meta-cognitive properties are emergent on a highly complex and non-simple multi-levelled dynamic system. These organisational features are in effects constraints, be it component or relational, and causally contribute to the meta-cognitive properties by dictating possible micro-level activity. Within these layers of emergence it is unclear where the move from weakly reducible to irreducible takes place and at what point meta-cognitive properties arise. Analysis of simple life forms and fossil records suggests that the meta-cognitive properties arose once the physical brain and its collective properties became sufficiently complex, although the exact level of complexity is unknown. So while meta-cognitive properties are often considered emergent due to perceived ontological distinction, the 'product of complex systems' approaches are still highly relevant.

While the investigatory purpose is driven by the nature of the mind, explanatory investigation is the tool by which this is achieved. As Searle (1992) notes, when we attempt to observe consciousness, we see only whatever it is we are conscious of. Thus difficulties in explanation are to be expected and cannot be taken as an indicator of ontologically strong emergence. That said, the emergentist investigations within the philosophy of mind focus around the nature of mind and there is little attempt to explore how theory, perceptions or our current state of knowledge contribute to the emergence.

In summary, in this section descriptions of seven classic emergents have been developed using the explanatory framework. The examples – (a) the property of being a circle, (b) thermodynamic properties, (c) the smell of ammonia, (d) the functionality of a machine, (e) the World Wide Web, (f) life and (g) mind – were chosen to capture interesting cases, illustrating particular problem areas or types of emergence. Before using these descriptions as a basis for further conceptual analysis, in the next section, the 'fitness' of the descriptions and their development are first considered.

7.2 Discussion of the descriptions of example emergents

As discussed in Chapter 3, subsection 3.2.3, before attempting to use the descriptions developed in section 7.1 in analytical discourse, the quality of the descriptions needs to be assessed. The most significant potential limitation of the explanatory framework, identified in subsection 6.2.1, is its feasibility in practice – i.e. (i) whether the desired information can actually be collected and (ii) whether a coherent description can thus be developed. Additionally, if the framework is to provide advantage over other explanatory approaches, then it should provide clarity regarding known 'problem areas'. This section, therefore, considers the development of the descriptions to assess both their fitness and that of the explanatory framework. First, the descriptions are examined to see if they brought clarity to difficult areas. This is followed by consideration of four key difficulties experienced in the description development process in order to examine whether they limit the fitness of the descriptions or that of the explanatory framework.

As discussed in subsection 3.2.3, p135, the seven examples of section 7.1 are deliberately chosen as they all feature aspects which, in the past, have proven difficult coherently to explain across different conceptualisations of emergence. Table 7-22 below summarises the particular problematic features and whether the descriptions developed using the explanatory framework may be said to bring clarity to the issue. There is no claim that the problem is resolved, only that clarity is improved.

Example	**Prior key explanatory problem**	**Clarification of problem using exploratory framework**
(a) Property of being a circle	Why are the macro-level properties apparently not contained in the micro-level components?	✓
(b) Thermodynamic properties	Are thermodynamic properties epiphenomena?	Partial
(c) The smell of ammonia	What exactly, if anything, is the emergent relation?	✓
(d) Functionality of a machine	What exactly, if anything, is the emergent relation? How does the emergence of planned and unplanned functionality differ?	✓ ✓

Example	Prior key explanatory problem	Clarification of problem using exploratory framework
(e) World Wide Web	What exactly is the emergence?	✓
(f) Biological life	What is life?	Partial
(g) Meta-cognitive properties	Are the macro-level properties irreducibility?	×

Table 7-22: Analysis of the success of the descriptions of section 7.1 in bringing clarity to problematic aspects of the emergents under consideration

As Table 7-22 above summarises[70], in all but one case, the descriptions of the seven example emergents offer clarity regarding the previously identified key problems associated with the conceptualisation of the phenomenon as emergent. For example, in the case of (c) the smell of emergence and (d) the functionality of a machine, the explanatory framework helps draw out that there are in fact multiple emergents and the particularly difficult issue of why the smell of ammonia or function of a machine is not contained in the component parts of ammonia or the machine respectively; rather in these cases the emergent phenomena are relational properties which lie between two emergents – the chemical properties of ammonia and the nasal receptors in the former case and the machine and the task done in the latter. While these points have been previously acknowledged in the literature, it is the structure of the explanatory framework and, in particular, its consideration of a wide emergence system that brings clarity by enabling these insights to be brought together in a coherent and 'transferable' way. In the case of example (b) thermodynamics, there is only partial clarity. The description of temperature illustrates that it is epistemological in nature, but that we cannot observe temperature without averaging and so to explain it *we* need to refer to a 'global property' of the system of component particles. The problem of how entropy results in the 'arrow of time' – see subsection 7.1(b) is not resolved. In the case of example (f), while the description does not answer the question what is life, it does illustrate that our concept of life arises from a group of processes and biological-level entities that emerge from chemical level components and their dynamics. The issue of the degree of

[70] The improved clarity is summarised in the conclusion of each description in subsections 7.1(a)-(g) respectively.

(ir)reducibility of meta-cognitive properties of mind is also not resolved. These problems are further discussed below where the implications of four key difficulties experienced in developing the descriptions are considered.

Firstly, lack of detailed scientific understanding of the 'mechanics' involved in some of the phenomena means that only provisional assessments can be made. This is most significant in the case of metacognitive properties of mind, where they were assessed as irreducible 'at present'. Similarly, lack of scientific understanding of the 'arrow of time' leads entropy to be assessed as possibly having irreducible macro-level causal powers. While these apparent characteristics may seem counterintuitive, there is insufficient evidence to say otherwise at present. But, as always, the degree of these characteristics may be downgraded from 'strong' to 'weak' as scientific understanding increases. Scientific understanding of abiogenesis is also still evolving. However, in this case there is reasonable scientific knowledge regarding the types of processes that need to have occurred rather than the exact processes and contexts. This, I claim, enables a reasonable, but generalised, description of this emergence.

Secondly, and relatedly, the description of meta-cognitive properties and, to a more limited extent the description of life, are also limited by the depth of researcher knowledge. This is not an intrinsic limitation of the explanatory framework as domain experts could assist in more detailed description development. However, analysis using the descriptions developed here must bear this limitation in mind.

Thirdly, difficulty was experienced in assessing the macro-level casual powers of some emergents. This difficulty arises from establishing what exactly the micro-level is and how two macro-level entities interact. For example, in the case of the Web, whether it has macro-level causal powers is open to interpretation. We certainly discuss the Web as a single entity when analysing its economic or social impact. Thus, the decision was taken to classify this as macro-level casual power. However, an alternative perception of the appropriate level for the Web might view this differently. The key point of the description is that it consists not just of the tables of properties relating to the emergence but also the surrounding discussions. While these descriptions may be longwinded, they provide the required context with which to place the assessment of the characteristics of the emergent.

Finally, this influence of perspective on levels etc means it is difficult to ensure consistency through the seven examples. Internal consistency of the description is not too problematic as the explanatory framework includes iterative cycling through the various stages. This iteration proved sufficient to identify and rectify internal inconsistencies. Achieving consistency across the seven examples – which is required if they are to be used in cross-analysis – is more difficult. This is largely due to the completely different contexts of each example. However, the subsequent conceptual analysis which is presented in section 7.3 below acts as check on consistency. For example, when carrying out cross-comparison of the key characteristics, unexpected differences in characteristics – i.e. differences which appear to be inconsistent with current understanding of say complex systems or epistemology – may be identified. The source descriptions can then be assessed and the explanatory framework reapplied where necessary, to assess whether the difference is due to inconsistency in application between examples or whether an interesting feature worthy of further conceptual analysis is being highlighted. This revision process is not problematic as it is in line with the pragmatic approach adopted within this research. The results presented in sections 7.1 and 7.3 are a result of this process and a simple cross-comparison of the properties is provided in Appendix A for reference. Further, the potential 'external' inconsistency is not a problem of the explanatory framework itself as the appropriate context is contained within the descriptions. However, it does potentially become an issue when particular features such as one word summaries of the key characteristics are abstracted from the detailed context. This potential issue must be considered when undertaking cross-analysis.

In this section the descriptions of emergents presented in section 7.1 and their limitations have been considered. Review of whether the descriptions improved clarity of areas which have previously been identified as problematic for each of the examples, led to the conclusion that the explanatory framework can aid clarity. However, four potential issues were identified: difficulty in gathering sufficient information where scientific understanding of the phenomenon is incomplete; lack of researcher domain expertise; difficulties establishing appropriate levels; and difficulties in ensuring consistency due to varying epistemological interpretations. These problems do not affect the fitness of the descriptions for use in conceptual analysis provided that the contextual information contained within the description is referred to and that the descriptions are pragmatically revised when inconsistencies become apparent. Further, the development of the descriptions in section 7.1 brings confidence in the usability of the explanatory framework. Having established that the seven descriptions of example emergents are fit for purpose, the next section uses these in conceptual analysis to help further assess the profitability of the broad conceptualisation, multi-tiered typology and explanatory framework.

7.3 Conceptual analysis

The seven neutral but conceptually-relevant descriptions of real-world emergents developed in section 7.1 provide a rich resource for use in conceptual analysis. While many different analyses could be undertaken, the analysis presented in this section focuses on addressing three key tasks pertinent to the overall research objectives. Firstly, in subsection 7.3.1, cross-analysis of the key characteristics and dimensions of the seven example emergents is undertaken in order to further assess the broad conceptualisation of emergence. Secondly, in subsection 7.3.2, cross-analysis of the types of emergence into which the seven example emergents may be grouped and how this supports generalisation, extrapolation and prediction is undertaken. This enables further assessment of the profitability of the multi-tiered typology. Finally, in subsection 7.3.3, further assessment of the explanatory framework is addressed. As a claimed key advantage of the explanatory framework is that it may be used to assess the broad conceptualisation and multi-tiered typology, this assessment of the explanatory framework achieved by considering the role of the descriptions of the example emergents and hence the explanatory framework in the preceding analyses.

7.3.1 Analysis to assess the broad conceptualisation of emergence

In Chapter 4, it is proposed that emergence may be profitably understood as (i) an inherently fuzzy concept, (ii) which is based around macro-level properties (emergents) which are not manifest in individual micro-level components in isolation and (iii) encompasses ontological, epistemological and complexity dimensions. While subsection 4.2.1 argues that this broad conceptualisation is plausible, as discussed in Chapter 3, subsection 3.2.3 the descriptions of example emergents developed in section 7.1 may be used in two ways to further assess plausibility. Firstly, cross-analysis of the claimed key characteristics relating to the seven example emergents can be used to further assess the claim that emergence is intrinsically fuzzy in nature – criterion (i) of the broad conceptualisation. Secondly, cross-analysis of the descriptions of examples may be used to assess whether they support the claim that the concept of emergence may be profitably understood in terms of ontological, epistemological and complexity dimensions – criterion (iii) of the broad conceptualisation. These two analyses are undertaken below, followed by a discussion of the limitations of the analyses and conclusions that may be drawn.

Cross-analysis of key characteristics

Cross-comparison of the claimed key characteristics, which are identified from the literature review in Chapter 2, section 2.4.3 will aid conceptual analysis of emergence and may be used to further assess the conceptual proposals. In particular, it is used in this subsection to further assess the claim that emergence is intrinsically fuzzy in nature. However, the cross-comparison is not straightforward for two reasons. Firstly, there are varying interpretations of what is meant by many of the characteristics – unpredictable or weakly irreducible being prime examples. Secondly, interpretation of the key characteristic depends greatly on the scope of the observations and analysis. Thus, instead of simply comparing whether a given example is considered to be characterised as unpredictable or irreducible, the underlying rationales for the key characteristics and the extent to which their characteristics are open to different epistemological interpretation also need to be included in the analysis.

This cross-comparison is achieved by examining whether each of the examples of section 7.1 can be characterised as having the key characteristics first identified in Chapter 2, section 2.4.3. For clarity, the key characteristics of being a micro-macro relation or novel are not included as the examples were selected on the basis that they satisfied these characteristics – i.e. criterion (ii) of the broad conceptualisation of emergence. This cross-analysis is summarised in Table 7-24 below, where the 'found' column indicates that there is evidence for the specified key characteristic in the appropriate explanatory description of section 7.1and the 'form' column indicates the form of key characteristic based on the classification of the related key characteristics within the explanatory framework. This, in most cases, is self-explanatory; however in the case of *Product of complex system* the 'forms' are taken from the construction generators of Table 6-2 (p181) and therefore contain forms such as manufacture which are not generally associated with complex systems, but can and do occur in them. '( )' is used to denote where there are potentially different opinions regarding whether a particular key characteristic is held by an emergent or what subtype it is. While this might make for a somewhat messy looking comparison, I would argue it is essential if a reasonable attempt at comparison is to be made. As discussed above, a more concise table would involve making invalid generalisations. Further, the splitting of the table into multiple tables would restrict the comparison across multiple emergents. Finally, the abbreviations used are as explained in Table 7-23 which immediately precedes the cross-analysis of Table 7-24. (Note: Table 7-23 below provides the key to the abbreviations used in the tables within this chapter.)

Before proceeding to the table, one consequence of the need to keep an open mind as to epistemological factors which is captured by the '( )', is briefly mentioned. This dependence on interpretation unfortunately arises from the nature of the concept of emergence and not to recognise this unavoidable subjectivity, which arises from how we interpret and understand emergents, I would argue, would be a serious error. The most immediate consequence for this analysis is that no statistical conclusions may be drawn from the data; rather what is of interest are broad patterns.

Abbreviation	**Meaning**	**Abbreviation**	**Meaning**
At	Attractor Reducible	PE	Prior Emergence
C	Component constraints	R	Relational constraints
Co	Constraining	Re	Resolution
CP	Complex product	Rn	Reasoning
D	Design	RP	Readily predictable
DC	Downward Causation	S	Sum
I	Irreducible	Sb	Subjectivity
IP	In principle	Sc	Scope
M	Macro constraints	SO	Self-organisation
Ma	Manufactured	U	Unpredictable
MCP	Macro Causal Power	×	No
O	Other	✓	Yes
Ob	Observation	()	Debateable
P	Product	-	Not applicable

Table 7-23: Key to abbreviations used in analysis tables

Table 7-24 below presents the cross-analysis of key characteristics associated with the seven example emergents.

Key characteristic / Example emergents	Unpredictable micro-macro relation		Irreducible micro-macro relation		Macro-level causal power		Downward causation		Product of complex system		Product of constraints	
	Found	Form	Found	Form	Found	Form	Found	Form	Found	Form	Found	Form
(a) Property of being a circle	×	-	×	-	×		×	-	×	-	✓	M
(b)-1 Temp.	×	-	×	-	✓	S	×	-	(×)	-	×	-
(b)-2 Entropy	×	-	(×)	-	✓	(I)	×	-	(×)	-	×	-
(c)-1 Properties of ammonia	×	-	✓	P	✓	P	×	-	✓	SO	✓	C
(c)-2 Realisation of smell of ammonia	✓	IP/ (U)	✓	CP	✓	P	×	-	✓	SO PE,Sb	✓	C,R
(d)-1 Characteristics of a machine	×	-	✓	P	✓	P	×	P	(✓)	Ma,D (PE, Sb)	✓	C,M
(d)-2 Planned Functionality of a machine	×	-	✓	CP	(✓)	(P)	×	-	(✓)	Ma,D (PE, Sb)	✓	C,M, R
(d)-3 Unplanned Functionality of a machine	✓	IP/ (U)	✓	CP/ (I)	✓	(P)	×	-	✓	SO,Ma,D , (PE, Sb)	✓	C,R
(e)-1 The Web	✓	IP	✓	CP	✓	CP	✓	Co	✓	SO Ma,D PE,Sb	✓	C,M
(e)-2 Structure of the Web	✓	IP	✓	CP	✓	P	✓	At	✓	SO,Ma PE,Sb	✓	C, (M)
(f)-1Abiogenesis	✓	IP	✓	CP	✓	CP	✓	Co	✓	SO,PE,S b	✓	C,M,R

Key characteristic / Example emergents	Unpredictable micro-macro relation		Irreducible micro-macro relation		Macro-level causal power		Downward causation		Product of complex system		Product of constraints	
	Found	Form	Found	Form	Found	Form	Found	Form	Found	Form	Found	Form
(f)-2 Biological life	✓	IP	✓	CP	✓	CP	✓	Co	✓	SO,PE,Sb	✓	C,M,R
(g)Metacognitive properties	✓	(U)	✓	(I)	✓	(I)	✓	(I)	✓	SO,PE,(Sb)	✓	C,(M),R

Table 7-24: Cross-analysis of key characteristics associated with the example emergents

Using Table 7-24 above, the evidence to support the proposal that emergence may be profitably understood as a fuzzy concept – criterion (i) of the broad conceptualisation is examined below.

As examination of the columns of Table 7-24 above illustrates, there is no single 'key characteristic' which is common to all of the example emergents save that of a novel macro-level property which is not manifest in its constituent micro-level parts. As discussed, this latter property is not included in Table 7-24 for clarity. If we were to exclude the property of being a circle from being emergent then, as column 6 illustrates, the possession of macro-level causal powers is a good candidate for a necessary characteristic for a phenomenon to be emergent. However, as the 'S' in column 7 indicates, the macro-level causal power relating to temperature is in effect a simple sum of the causal powers of lower-level component parts. Thus we would also have to exclude temperature. Additionally, as the '( )' illustrates, whether functionality of a machine can be said to possess macro-level causal powers is debateable. Thus, the possession of micro-level causal powers does not lend itself to being considered a necessary and sufficient condition for emergence within the broad conceptualisation. Downward causation, as column 8 illustrates, is possessed by even fewer examples and again is the subject of debate. Thus, downward causation too is not viable as a necessary and sufficient condition. As column 10 illustrates, being a product of a complex system is also not a suitable necessary condition if thermodynamic properties are to be included[71]. Likewise, column 12 illustrates that these cannot be said to be the product of constraints either. Thus, Table 7-24 illustrates that (a) there are no key characteristics shared by all and hence no general necessary and sufficient conditions and (b) that the perceived key characteristics are still dependent on interpretation. Thus, these two factors, I would argue, further substantiate the fuzzy nature of the concept of emergence – i.e. they support criterion (i) of the broad conceptualisation of emergence.

Cross-analysis of dimensions

In Chapter 4, it is argued that the concept of emergence has three dimensions – ontological, epistemological and complexity. In this subsection, the explanatory descriptions of the example emergents developed in section 7.1 are cross-analysed to assess whether there is evidence to support this claim (criterion (iii) of the broad conceptualisation). This is achieved by examining, for each example emergent, whether there is evidence that reference to characteristics relating to the three dimensions is necessary to adequately explain the emergent. So for example, the realisation of the smell of ammonia might be viewed as having an ontological component as it is not simply reducible to its components parts (Table 7-10, p223); it has an epistemological component because this interpretation depends on the scope of analysis (Table 7-10, p223) and has epistemological generators as observation plays an integral causal role (Table 7-11, p225); and has complexity component because it is generated by non-linear component and relational constraints and developed through self-organisation (Table 7-11, p225).

This cross-analysis of the examples of section 7.1 is summarised in Table 7-25 below, where the 'found' column indicates that there is evidence for the dimension in the relevant explanatory description of section 7.1 and the 'form' column indicates the form of dimension-related evidence, based on the classification of the related key characteristics within the explanatory framework. This inclusion of subanalysis of form is useful due to the ongoing disagreements. For example, there is still disagreement regarding whether weakly reducible emergents can be truly classified as ontological. Epistemological generators and epistemological influences are included as separate forms as they play quite a different role

[71] The '()' in this case does not derive directly from the descriptions but has been included as Bar-Yam (2004) claims that imperfections in materials mean that any system with temperature contain non-linear dynamics in practice. However, this does not contribute to current theoretical understanding of temperature.

in explaining an emergent. The former playing a causal role in the generation of the phenomenon and the latter is related to how our knowledge and understanding affects our perception of the phenomenon as emergent. If either of these roles features in the description then I contend that this provides evidence for an epistemological dimension to emergence.

Again, '( )' is used to denote where there are potentially different opinions on whether the emergent is a result of characteristics relating to the specific dimension. For example, '( )' is used in row 2, column 2 to capture the fact that Bedau states that the property of being a circle is ontologically emergent although this was not really borne out in the explanatory description of subsection 7.1(a); the other '( )' in column 2 indicate that to some the irreducibility is not ontological as it is a complex product; and the '( )' in column 6 indicate that there is no evidence of self-organisation which to some is a key requirement of complex systems. Abbreviations are as explained in Table 7-23, p254. The cross-analysis and conclusions that can be drawn are discussed below.

Dimensions / *Example emergents*	**Ontological**		**Epistemological**			**Complexity**	
	Found	**Form**	**Found**	**Form generator**	**Form influence**	**Found**	**Form**
(a) Property of being a circle	(×)	-	×	-	-	(✓)	M
(b)-1 Temperature	×	-	✓	Ob	Re,	×	-
(b)-2 Entropy	(✓)	MCP:(I)	✓	Rn	Re,	×	-
(c)-1 Properties of ammonia	(✓)	P MCP:P	×	-	-	✓	C,SO
(c)-2 Realisation of smell of ammonia	(✓)	CP MCP:P	✓	Ob	(Sc),	✓	C,R,SO
(d)-1 Characteristics of a machine	(✓)	P MCP:P	✓	(Ob,Rn)	(Re)	(✓)	C,M
(d)-2 Planned Functionality of a machine	(✓)	P (MCP:P)	✓	Ob,Rn,	(Re)	(✓)	C,M,R
(d)-3 Unplanned Functionality of a machine	(✓)	CP (MCP:P)	✓	Ob, Rn,	(Sc,Re)	✓	C,R,SO

Example emergents \ Dimensions	Ontological		Epistemological			Complexity	
	Found	Form	Found	Form generator	Form influence	Found	Form
(e)-1 World Wide Web	(✓)	CP MCP:CP DC:Co	✓	Ob,Rn	(Re)	✓	C,M,SO
(e)-2 Structure of Web	(✓)	CP MCP:P DC:At	✓	Ob,Rn,	(Re), (Sc)	✓	C,(M), SO
(f)-1 Abiogenesis	(✓)	CP MCP:CP DC:Co	×	-	(Re)	✓	C,M,R, SO
(f)-2 Biological life	(✓)	CP MCP:P DC:Co	×	-	(Re)	✓	C,M,R, SO
(g) Meta-cognitive properties	(✓)	I/CP MCP:I DC:I	(✓)	(Ob)	(Re),(Sc)	✓	C,(M), R,SO

Table 7-25: Cross-analysis of ontological, epistemological and complexity factors relating to the example emergents

Three broad patterns can be observed in the cross-analysis of Table 7-25 above.

Firstly, as comparisons of columns 2, 4 & 6 illustrate, for each example emergent, at least one of ontological, epistemological and complexity-related factors contribute to the emergence. This spread gives further confidence that these three dimensions adequately span the conceptual domain of emergence.

Secondly, comparison of columns 2 & 6 illustrates a strong correlation between ontological and complexity-related factors. This is as expected because, as noted in Chapter 4, section 4.2.1, complexity could reasonably be construed as an ontological factor. The fact that '( )' in column 2 indicates a possible doubt whereas in most cases the corresponding entry in column 6 is not conditional illustrates the advantage of inclusion of complexity as it provides more information and is not dependant on a particular philosophical stance regarding the degree of (ir)reducibility that relates to emergence.

Thirdly, as the '( )' in column 2 of Table 7-25 illustrate, there is disagreement regarding whether there are ontological components to the example emergents. Here the '( )' capture the difference in opinion regarding whether macro-level phenomena which are reducible in principle only to their component parts should be considered as ontologically emergent. As discussed in Chapter 2, section 2.3.1, strong emergentists would not consider such phenomena emergent since they are not ontologically novel – i.e. they do not represent a new level of reality. However, I would argue that the explanatory descriptions of examples 7.1 (c) – (g) clearly illustrate that we need to include significant description of not just the component parts but how they are related in any reasonable explanation of these emergents. Thus, non-simple ontological factors clearly play a part in both examples (c) – (g) and in many conceptualisations of emergence. This issue and pattern will be returned to in subsection 7.3.3.

In conclusion, the above cross-analysis lends weight to the coverage of the domain by and usefulness of the identified dimensions. Thus, I contend, this analysis lends further weight to criterion (iii) of the broad conceptualisation of emergence – that emergence might be profitably understood through a conceptualisation which encompasses ontological, epistemological and complexity dimensions.

Limitations of the analysis and conclusions

Two potential limitations relating to the cross-analysis of the key characteristics and the conceptual dimensions can be identified. Firstly, the analysis clearly depends on the fitness of the seven descriptions of emergence. As discussed in section 7.2 there may potentially be inconsistencies in the seven descriptions; however these were minimised as discussed in section 7.2. Secondly, as the '( )' in Table 7-24 and Table 7-25 indicate, differing epistemological interpretations may affect perception of the characteristics or dimensions. This is overcome by the inclusion of 'form' information in both tables.

As the limitations have been minimised, I argue that the cross-analysis of the key characteristics and associated conceptual dimensions relating to the seven descriptions of examples emergents further support the plausibility of the criteria (i) and (iii) of the broad conceptualisation of emergence.

7.3.2 Analysis to assess the usefulness of the multi-tiered typology

As discussed in Chapter 5, the driver for the multi-tiered typology is to focus and conceptually found communication and analytical discourse within an interdisciplinary context. In particular, the multi-tiered typology is designed to support communication and generalisation as well as higher order analysis activities such as prediction and extrapolation. As illustrated in section 5.1, the interdisciplinary discourse supported by the multi-tiered typology may be regarding either individual conceptualisations of emergence or putative emergent phenomena. The discussion of subsection 5.2.2 also highlights additional advantages of the multi-tiered typology – that it elaborates the broad conceptualisation, facilitates development of shared meaning and aids identification of boundary objects and their characteristics within interdisciplinary discourse. Thus, the multi-tiered typology has a number of planned and unplanned functions and, to a large extent, its usefulness and hence profitability depends on how successful it is in serving these functions. This subsection uses the explanatory descriptions of the example emergents developed in section 7.1, in combination with the multi-tiered typology, to assess this functionality and hence the potential usefulness of the multi-tiered typology.

The multi-tiered typology is an idealised type typology built from consideration of the various conceptualisation of emergence found within the literature. As discussed in sections 5.1 and 5.2, it captures the domain extremes and interesting cases and as a consequence of this structure, individual emergents might not necessarily fit into a specific type/subtype within the typology. However, subsections 5.1(a) & (b) provide examples of how the typology might usefully be utilised to explore individual conceptualisations of emergence and emergents respectively. Clearly, the example emergents of section 7.1 only allow the claimed functionality with respect to emergents and not individual conceptualisations to be assessed. Therefore, the assessment presented here will concentrate on assessing the analysis activities identified in subsection 5.1(b). This, I argue, is sufficient to give a reasonable indication as to the potential usefulness of the multi-tiered typology.

The subsection proceeds as follows. First, the matching of the example emergents using the typology is present in Figure 7-8 and discussed. These categorisations are then used to explore whether first comparisons and generalisation and then predictions and extrapolations regarding the emergents can be made. This is followed by a brief discussion of practical limitations of the analysis and conclusions that may be drawn.

Loose matching of the example emergents

As discussed in Chapter 5, section 5.1, potentially emergent phenomena may be grouped either strictly or loosely using the types/subtypes of the multi-tiered typology. In the former case, a phenomenon is matched with the type/subtype if and only if the emergent is exclusively of the top tier type in nature – i.e. exclusively a product of ontology, epistemology or complexity. In the latter case, matching merely indicates that a phenomenon has ontological, epistemological or complexity-related contributing causal factors. Loose matching is most relevant to the task at hand. The result of the loose matching processes is presented in Figure 7-8, p264.

The loose matching process used to generate Figure 7-8 is in general self-explanatory, with for example a phenomenon being matched to *//Product_of_complex_system/ Macro_pattern-structure|processes/Non-linear_dynamics* if self-organisation contributes to its generation and to *//Ontological_novelty/Macro_property* if it is ontologically irreducible, with the specific degree of irreducibility – i.e. nominal, weak or strong - being noted. However, the loose matching with respect to *//Epistemological_novelty/ Macro_phenomenon/Relative_to_theory|knowledge* needs some further explanation. In this type/subtype there are two key characteristics *non-deducibility* and *unpredictability.* A phenomenon is loosely matched as non-deducible if, for a given resolution (i.e. theory and/or knowledge and/or language at a given scale) or scope, the macro-level phenomenon cannot be deduced from the relevant micro-level theory and/or knowledge and/or language. So for example, thermodynamic properties are loosely matched as *//Epistemological_novelty /Macro_phenomenon/Relative_to_theory|knowledge/Non-deducible/Resolution* as neither the language nor theory of the macro-level is part of micro-level statistical mechanics. The matching of phenomena that are not directly related to a theory is more difficult. For example, consideration of whether the Web is deducible from micro-level theory is problematic as there are numerous different theories which could be considered, some of which facilitate deducibility and some do not, at least at present. Such cases are simply matched with a '?'. Additionally, it should be noted that scope and resolution are not exclusive as both may affect the matching. A phenomenon is similarly loosely matched as unpredictable. In this case, it needs to be remembered that scope may extend in both space and time. Thus, phenomena which are apparently unpredictable because of their non-linear structure, but are predictable in principle if the initial conditions are known and sufficient computational power and time are available, are loosely matched to *//Epistemological_novelty/Macro_phenomenon/Relative_to_theory|knowledge / Upredictability/(Scope)*.The '( )' captures the fact that such phenomena might be practically unpredictable. A phenomenon is loosely matched to *//Epistemological_novelty/ Macro_phenomenon/Model_change/Conceptual* if the macro-level concept does not exist in the micro-level. So for example, thermodynamic temperature is matched as it is conceptually different from the kinetic energy of micro-level components; but the structure of the Web is not because the macro-level structure is simply conceptualised in terms of the linkages between micro-level components and not as something different. The purpose here is not to identify some phenomena as emergent relative to conceptual models and others not; rather it is to encourage consideration of the different conceptual models with which a phenomenon is described. Finally, a phenomenon is loosely matched to *//Epistemological_novelty/Macro_phenomenon/Model_change/Predictability* if the macro-level theory or conceptualisation enables better prediction of behaviour than any micro-level theory. So for example, the property of being a circle is not thus matched because the circle may be predicted from the co-ordinates of the points. On the other hand, the functionality of a machine is matched as it cannot be predicted from machine components alone.

Figure 7-8 then presents the results of this loose matching of the examples from section 7.1. Each of the individual emergents referred to in the development of these descriptions is considered. For each type/subtype, the result for each identified key characteristic is presented in a box at the foot of the corresponding column. For clarity, the example is identified by its subsection letter and a corresponding key is provided. Finally, as in the preceding analysis of subsection 7.3.1, '( )' is used to indicate areas where there is a degree of uncertainty. In this case, the uncertainty arises from lack of knowledge of the internal structure and dynamics of the emergence rather than as a result of potentially differing interpretations that depend on philosophical stance. The output from this matching exercise is then used in the subsequent analysis.

Figure 7-8: Loose matching of example emergents using the multi-tiered typology

Figure 7-8 illustrates how the multi-tiered typology can be used to group (categorise) the seven descriptions of example emergents developed in section 7.1 as part of a loose matching process. As described in Chapter 5, section 5.1 the multi-tiered typology is based, at its top tier, on the three basic approaches to emergence – ontological novelty, epistemological novelty and a product of a complex system. Each top-tier type is then subdivided into different views regarding the core features of emergence, which are found within the general overarching approach. These views consist of what the emergent phenomenon is – represented by the tier 2 labels, which are then subdivided again, where appropriate into particular sub-views. – tier 3. Each tier 3 label – e.g. *Downward_causation, Constraints* or *Phenomenological* etc. – is simply the label for the view and therefore, as in the case of *//Epistemological_novelty/Macro_phenomenon/Relative_to_theory|knowledge /*, it may have multiple associated key characteristics. The key characteristics are presented in tier 4. For simplicity, they are not directly connected to the tier 3 nodes as for example *Irreducibility* might be the key characteristic of multiple sub-nodes as illustrated in *//Ontological_novelty/Macro_entity|rules/Hierarchy, //Ontological_novelty /Macro_entity|rules/Macro_entity_causal_power* and *//Ontological_novelty/ Macro_entity|rules/Downward_causation.* The various forms of each key characteristic are attached at tier 5, where appropriate. Finally, directly underneath the multi-tiered typology, the result of the loose matching process is presented. For each type/subtype of the typology, the loose matches from the seven descriptions of example emergents are presented in a box at the foot of the corresponding type/subtype column.

Three general patterns can be identified within the loose matching presented in Figure 7-8. Firstly, all example emergents can be loosely matched to at least one branch (leaf) of the multi-tiered typology. Secondly, each leaf of the typology has at least one example matched to it. These two observations provide further confidence in the coverage and usefulness of the multi-tiered typology. Thirdly, the categorisation is not unique as many examples can be loosely matched to multiple types. This is not problematic as the multi-tiered typology is an idealised type and therefore unique categorisation is not required.

The multi-tiered typology can be used as captured in Figure 7-8 to undertake comparison and generalisation analyses as discussed in subsection 5.1(b).

Comparison and generalisation

As Figure 7-8 illustrates, the examples can be loosely matched onto a number of different types/subtypes. These matches can be used to explain why and in what circumstances a particular example might be considered emergent. For example, consider examples (b)-1&2 – the thermodynamic properties of temperature and entropy – which loosely match to the types/subtypes listed in Table 7-26 below.

Multi-tiered typology type/subtype	Temperature	Entropy
//Ontological_novelty/Macro_property/Irreducibility/Nominal	✓	✓
//Ontological_novelty/Macro_entity|rules/Macro_entity_causal_power/Irreducibility/Strong	×	(✓)
//Epistemological_novelty/Macro_phenomenon/Phenomenological/Surprise	×	✓
//Epistemological_novelty/Macro_phenomenon/Phenomenological/New	✓	✓
//Epistemological_novelty/Macro_phenomenon/Relative_to_Theory|Knowledge /Unpredictable/Resolution	✓	✓
//Epistemological_novelty/Macro_phenomenon/Relative_to_Theory|Knowledge /Non-deducible/Resolution	✓	✓
//Epistemological_novelty/Macro_phenomenon Model_change/Conceptual	✓	✓

Table 7-26: Summary of the multi-tiered typology types/subtypes to which thermodynamic properties can be loosely matched

As the loose matching of the descriptions of thermodynamic properties with the types/subtypes of the multi-tiered typology captured in Figure 7-8 and Table 7-26 illustrates, the perception of thermodynamic properties as emergent is clearly dependent on the particular perspective on emergence adopted. This is most readily illustrated by the fact that apart from *//Epistemological_novelty* related types, temperature only matches *//Ontological_novelty/Macro_property/Irreducibility/Nominal.* As discussed in Chapter 2, subsection 2.4.1, strong emergentists and indeed many weak emergentists do not consider phenomena which are nominally irreducible as emergent. Thus, the matching process illustrates that temperature is in general only considered emergent in the sense of epistemological novelty. The possible loose matching of entropy to *//Ontological_novelty/Macro_entity/Irreducibility/Strong* illustrates that the picture is not quite so clear cut and that entropy may have potentially ontological consequences. Thus, the matching of the thermodynamics properties illustrates a significant epistemological basis to the phenomena. From this matching and the properties of the multi-tiered typology, it can be concluded that under many conceptualisations, thermodynamics properties are not considered emergent. However, their epistemological features make them extremely useful examples when trying to assess what is meant by emergence. Further, the fact that entropy has potentially strong causal powers, in contrast with no complexity-related components and nominal irreducibility, I would suggest, strongly indicates a potential contradiction or at least a counter-intuitive feature, suggesting it is an area which requires deeper investigation.

The preceding multi-tiered typology-supported analysis provides additional contextual information to that gathered by the explanatory framework as the latter deals only with the 'neutral' key characteristics of the phenomenon and not perceptions of the concept of emergence. This is more clearly illustrated in the case of the World Wide Web and its structure (example (e)-1,2), for which there is not an extensive history of use in conceptual discourse regarding emergence. The loose matching of the World Wide Web and its structure is summarised in Table 7-27 below followed by a discussion of how it can be used to explain why and in what circumstances these phenomena might be considered emergent.

Multi-tiered typology type/subtype	**Web**	**Structure of the Web**
//Ontological_novelty/Macro_property/Irreducibility/Weak	✓	✓
//Ontological_novelty/Macro_entity|rules/ Macro_entity_causal_power/Irreducibility/Weak	✓	✓
//Ontological_novelty/Macro_entity|rules/ Downward_causation/Irreducibility/Weak	×	✓
//Ontological_novelty/Macro_entity|rules/ Downward_causation/Irreducibility/Medium	✓	×
//Epistemological_novelty/ Phenomenological/New+Surprise	✓	✓
//Epistemological_novelty/Macro_phenomenon/Relative_to_ Theory|Knowledge/Unpredictable/Scope	(✓)	(✓)
//Epistemological_novelty/Macro_phenomenon/Relative_to_ Theory|Knowledge/Non-deducible	?	?
//Epistemological_novelty/Macro_phenomenon Model_change/Conceptual	✓	×
//Epistemological_novelty/Macro_phenomenon Model_change/Predictability	✓	✓

Multi-tiered typology type/subtype	Web	Structure of the Web
//Product_of_complex_system/Macro_patterns-structure|processes/Constraints/Component	✓	✓
//Product_of_complex_system/Macro_patterns-structure|processes/Constraints/Macro	✓	(✓)
//Product_of_complex_system/Macro_patterns-structure|processes/Non-linear_dynamics/Self-organisation	✓	✓

Table 7-27: Summary of the multi-tiered typology types/subtypes to which the emergence related to the Web can be loosely matched

As the focus on the complex network structure (Adamic 1999, Albert 1999) which has emerged as the Web developed illustrates, there is clearly considerable interest in the Web from the complex systems community. Thus, at first glance, the emergence of the Web and its structure might be expected to be of interest predominately to the complex systems movement and those interested in weak ontological emergence. However, as the loose matching of the descriptions of the Web and its structure with the types/subtypes of the multi-tiered typology captured in Figure 7-8 and Table 7-27 illustrates, the Web and its structure exhibit features generally associated with epistemological novelty as well as that relating to ontological novelty and product of complex system related types of emergence.

For those interested in emergence as the product of a complex system, it is in general the element of self-organisation which is of most interest. However, the Web also maps to *//Product_of_complex_system/Macro_patterns|processes/Constraints/Component +Macro.* I would suggest, examination of these different types of generating constraints may increasingly be of interest, as understanding of their general role in emergence improves. This is important because as the Web continues to evolve, the loci of control is increasingly moving from semi-engineered towards directly user-generated content and services without any significant engineering. As a result we are increasingly seeing multiple types of constraints affecting Web development.

For those interested in epistemological influences regarding emergence, the Web is of significant interest. The *//Epistemological_novelty/Macro_phenomenon/ Relative_to_theory|knowledge /Unpredictable* loose matching arises from the non-linearity of the related emergence system, where its principles, if not practice, are increasingly understood. However, I would suggest that it is under the */Model_change*-related approaches to emergence that significant new interest may arise. The Web loosely matches to

//Epistemological_novelty/Macro_phenomenon/Model_change/Conceptual+Predictability because we both conceptualise and make predictions regarding the Web at the macro-level. Consideration of these two sub-approaches, I would suggest, offers a way of considering how we understand and affect the Web. For example, it may be relevant to consider whether it is simply our conceptualisation that causes this model change or whether it is related to the information and hence causal structure within the Web itself.

Thus, as the preceding two examples illustrate, the loose matching of Figure 7-8 can be used to explain why and in what circumstances a particular example might be considered emergent. In particular, it illustrates where the emergent lies within the broad conceptual domain of emergence.

Prediction and extrapolation

It is additionally claimed, in section 5.1, that the multi-tiered typology may support prediction and extrapolation. This may be achieved as follows.

Firstly, as the multi-tiered typology is built from the extensive review and synthesis of existing literature on emergence, its prediction capabilities consequently draw heavily on existing approaches/conceptualisations. However, the particular advantage it offers is that it supports comparison across the broad conceptual space relating to emergence and hence predictions may be made that span the boundaries of particular conceptualisations. For example, through the *//Product_of_complex_system/Macro_patterns-structure|processes/ Constraints/Component* type/subtype, the multi-tiered typology captures the fact that to complex systems scientists prospective emergents may be found in complex systems. Thus, it 'predicts' where a certain type of emergent lies. It further captures (indicates) that such a phenomenon is likely to be considered emergent to weak emergentists through the *//Ontological_novelty/Macro_property/Irreducibility/Weak* type/subtype.

Secondly, the multi-tiered typology also, I claim, enables extrapolation based on how a new example fits into the model. This can be achieved where there is evidence that phenomena which loosely match to a specific intersection of types/subtypes share a common set of characteristics. In such cases, I argue, it is reasonable to extrapolate that other phenomena which also match the specific group of types/subtypes may also share the same set of characteristics. For example, as Figure 7-8, p264 captures, examples (d)-1,2: the characteristics of a machine and its planned functionality, (e)-1,2: the Web and its structure, (f)-1,2: abiogenesis and biological life and (g): the meta-cognitive properties of mind all loosely match onto *//Product_of_complex_system/Macro_patterns-structure|processes/*

Constraints/Component+Macro, //Ontological_novelty/Macro_entity|rules/ Macro_entity_causal_power/Irreducibility and *//Epistemological_novelty /Macro_phenomenon/Model_change/ Predictability.* Cross-comparison of their characteristics, extracted from the descriptions of section 7.1, is presented in Table 7-28 below. Where relevant, the particular form of the characteristic and how it may be influenced due to epistemological considerations is included, to facilitate consistency of analysis.

Example \ Characteristic		(d)-1	(d)-2	(e)-1	(e)-2	(f)-1	(f)-2	(g)
Surprise	*Form*	×	×	(✓)	✓	×	×	×
Predictability of emergent	*Form*	RP	RP	IP	IP	IP	IP	U/(IP)
	Epi influence	×	×	×	(Re)	(Re)	(Re)	(Re)
Reducibility of explanation	*Form*	P	CP	CP	CP	CP	CP	I/(CP)
	Epi influence	×	×	×	×	×	×	(Re)
Component constraints	*Form*	☑	☑	☑	☑	☑	☑	☑
Macro constraints	*Form*	☑	☑	☑	[✓]	☑	☑	?
Relational constraints	*Form*	×	✓	×	×	✓	✓	✓
Self-organisation	*Form*	×	×	✓	✓	✓	✓	✓
Manufacture	*Form*	✓	✓	✓	✓	×	×	×
Design	*Form*	✓	✓	✓	×	×	×	×
Prior emergence	*Form*	[✓]	☑	☑	(×)	☑	☑	☑
Subjectivity	*Form*	[✓]	☑	☑	(×)	☑	☑	[✓]
Observation	*Form*	(✓)	✓	✓	✓	×	×	×
Reasoning	*Form*	(✓)	✓	✓	✓	×	×	-
Scope	*Form*	×	×	×	×	✓	×	×
Resolution	*Form*	(✓)	×	×	×	(✓)	×	(✓)
Macro-level causal power	*Form*	P	(P)	CP	P	CP	CP	(I)
	Epi influence	×	(Re)	×	×	×	×	(Re)
Downward causation	*Form*	×	×	Co	At	Co	Co	(I)
	Epi influence	×	×	×	×	×	×	(Re,Sc)

Table 7-28: Cross-comparison of characteristics of examples emergents which match to a specific set of types/subtypes

As Table 7-28 illustrates, all the examples match to component constraints. Additionally, as the highlighting in Table 7-28 illustrates, five characteristics can be identified which all but one example emergent fits – reducibility of explanation as a (complex) product, prior emergence, subjectivity, macro constraints and macro-level causal power as a (complex) product of micro-level powers. For example, all examples bar (e)-2 match onto 'prior emergence'. Further, as the '()' in each non-matching example illustrate, there is a possibility that these too could match depending on interpretation or improved knowledge. This cross-comparison, I argue, provides evidence of a possible correlation between the characteristics of phenomena which loosely match to the four specified multi-tiered typology types/subtypes. It therefore suggests that it might be reasonable to extrapolate that other emergents which match the same four types/subtypes of the multi-tiered typology will also possess most of these characteristics.

These two claims – (i) that novel, macro-level products of a complex system can be 'predicted' (i.e. inferred – see subsection 3.2.3, p119) to loosely match onto *//Product_of_complex_system/Macro_patterns-structure|processes/Constraints/Component* and *//Ontological_novelty/Macro_property/Irreducibility/Weak* and (ii) that it can be extrapolated that they may be generated by component constraints, macro constraints, prior emergence and subjectivity; their explanation is 'reducible' to a (complex) product of micro-level component parts and their macro-level causal power is a (complex) product of micro-level powers – are assessed by drawing on a separate empirical investigation of emergence within synergy-driven learning communities (McDonald 2005, McDonald and Weir 2006). In these separate qualitative case studies, a number of emergents had been identified and examined in detail. Using this qualitative study as a source, descriptions of two sample emergents are developed using the explanatory framework. These are presented in Appendix B along with an introductory overview of each emergence taken from the original work. The resulting descriptions of (h) collective memory within DIDET and (j) social capital within REAL can then be loosely matched with the multi-tiered typology. The result of this process is presented in Figure 7-9 below.

Figure 7-9: Loose matching of examples (h) and (j) using the multi-tiered typology

Figure 7-9, p272 captures the results of the loose matching of (h) collective memory within DIDET and (j) social capital within REAL, using the descriptions presented in Appendix B. As might be expected, as both emergents are the result of complex socio-technical systems, their loose matching is identical except for the evidence of relational constraints contributing to the social capital accessible to an individual – (j)-2 – which was not found in the case of emergents (h) or (j)-1. The main significant difference between the loose matching of examples (h) and (j)-1,2 and the earlier loose matching of examples (a)-(g) is that in this case none of the emergents are matched to *//Epistemological_novelty/Macro_phenomenon/Model_change/Conceptual.* This is because the concepts of collaboration and social capital can be applied, albeit incompletely, to individuals – i.e. while they obtain their value at the macro-level, the concept can reasonably be referred to at the level of the individual. In such cases, I argue, it is not reasonable to loosely match such examples to *//Epistemological_novelty/Macro_phenomenon/Model_change/Conceptual.*

As both examples arise in complex socio-technical systems, by the earlier discussion it can be predicted that they should loosely match onto *//Product_of_complex_system/Macro_patterns-structure|processes/Constraints/Component* and *//Ontological_novelty/Macro_property/Irreducibility/Weak.* As predicted, Figure 7-9 clearly illustrates that both examples loosely match onto these types/subtypes. Thus, examples (h) and (j)-1,2 lend weight to the predictive capabilities of the multi-tiered typology.

As discussed earlier, loose matching of examples (h) and (j) presented in Figure 7-9 can also be used to assess whether the multi-tiered typology can support extrapolation. As can be observed, both examples loosely match to *//Product_of_complex_system/Macro_patterns-structure|processes/Constraints/Component+Macro, //Ontological_novelty/Macro_entity|rules/Macro_entity_causal_power/Irreducibility* and *//Epistemological_novelty/Macro_phenomenon/Model_change/Predictability.* Thus, using Table 7-28 p270, it can be extrapolated that emergents (h) and (j)-1,2 should have the following characteristics: generated by component constraints, macro constraints, prior emergence and subjectivity; explanation is 'reducible' to a (complex) product of micro-level component parts and macro-level causal power is a (complex) product of micro-level powers.

To assess whether this is indeed the case, the characteristics of the examples (h) and (j)-1,2 are cross-compared with these predictions in Table 7-29.

Characteristic / Example		(h)	(j)-1	(j)-2	Prediction
Surprise	*Form*	×	×	×	
Predictability of emergent	*Form*	IP	IP	IP	
	Epi influence	×	×	×	
Reducibility of explanation	*Form*	CP	CP	CP	CP
	Epi influence	×	×	×	
Component constraints	*Form*	☑	☑	☑	☑
Macro constraints	*Form*	☑	☑	☑	☑
Relational constraints	*Form*	×	×	✓	
Self-organisation	*Form*	✓	✓	✓	
Manufacture	*Form*	(✓)	×	×	
Design	*Form*	✓	✓	✓	
Prior emergence	*Form*	☑	☑	☑	☑
Subjectivity	*Form*	☑	☑	☑	☑
Observation	*Form*	✓	×	✓	
Reasoning	*Form*	(×)	×	(✓)	
Scope	*Form*	(✓)	(✓)	(✓)	
Resolution	*Form*	(✓)	(✓)	(✓)	
Macro-level causal power	*Form*	P	P	[P]	P
	Epi influence	×	×	×	
Downward causation	*Form*	At	At	Co	
	Epi influence	×	×	×	

Table 7-29: Cross-comparison of characteristics of examples (h) and (j)

As Table 7-29 illustrates, the characteristics of examples (h) and (j)-1,2 match with those extrapolated from the earlier loose matching of examples (a)-(g) – highlighted in column 6. Thus, this cross-analysis of characteristics, I argue, further supports the claim that the multi-tiered typology can support extrapolation.

It can also be observed from Table 7-29 that emergents (h) and (j)-1,2 have similar characteristics except for the element of manufacture found in (h), relational constrains in (j)-2 and lack of observation or reasoning contribution in (j)-1. This degree of common characteristics is as expected given that the example emergents were all formed in complex socio-technical systems.

Before discussing the limitations and conclusions of this analysis of the profitability of the multi-tiered typology, one other form of prediction can be identified. Phenomena which loosely match multiple types/subtypes are 'boundary objects' in that they can be used to explore different conceptualisations and the concept of emergence in general. Thus, social capital and collaboration should be boundary objects. This was indeed found to be the case in the empirical learning communities study where social capital proved to be a useful 'tool' with which to discuss the concept of emergence during the various different practitioners interviews. Thus, the multi-tiered typology can also be used to predict boundary objects.

Limitations of the analysis and conclusions

Three potential limitations relating to the loose matching process, upon which the analysis of the capabilities of the multi-tiered typology is based, can be identified.

Firstly, the loose matching process is subjective in nature. This is unavoidable given the parsimony of the multi-tiered typology. The subjectivity itself is not an issue as there is no preferred or correct interpretation; however to ensure the validity of the analysis is not compromised, it is essential that the loose matching is coherent (makes sense) and is consistently applied across all the matching processes used in the analysis. To minimise the effects of this limitation, the loose matching processes were made explicit and the results reanalysed to check for consistency. Further, as discussed in Chapter 6, the real value is in the discussion regarding the loose matching and not solely the final result of the analysis. Secondly, the validity of the analysis is also dependant on the fitness of the descriptions of the emergents. As discussed previously, there may potentially be inconsistencies in the descriptions; however these were minimised as discussed in section 7.2. Thirdly, the analysis carried out was not empirical except for the two learning community examples and even then secondary data was used. This, together with the size of sample, means that no statistical or indeed firm conclusions may be drawn. However, I would argue that the analyses presented here are indicative of what can be carried out. Other example sets could be used and different intersections of loose mappings identified to facilitate prediction and extrapolation regarding emergence.

Thus, as the limitations have been minimised, I argue, it can be concluded from the preceding analysis of the comparison and generalisation, and prediction and extrapolation capabilities that the multi-tiered typology of emergence is a profitability tool for conceptual analyse of emergents and emergence.

7.3.3 Conclusions regarding the explanatory framework

The explanatory framework introduced in Chapter 6 is designed to support neutral but conceptually-relevant descriptions of emergent phenomena. As discussed in subsection 6.2.1, key factors which affect its profitability are that it enables adequate coverage of the instantiation, causation and behaviour of the phenomenon under discussion and that it adequately covers the phenomenon's causal environment – without these two capabilities the explanation it helps develops will be extremely limited. The explanatory framework is specifically designed to address these areas through stages 2-4 and stage 1 respectively. As I conclude in subsection 6.2.1, the real test of usefulness of the explanatory framework is whether or not it can be used to develop coherent descriptions of emergents which can then be used in analytical discourse to improve understanding of emergence. Further, as discussed in subsection 6.2.2, the explanatory framework also has the potential advantage that it can be used as a tool for assessing the other conceptual proposals – the broad conceptualisation and multi-tiered typology. How the analyses of this section and the previous section support the profitability of the explanatory framework is considered below. This is followed by a brief discussion of limitations and conclusions that may be drawn.

The analysis of this section, I argue, further substantiates the usefulness of the explanatory framework in two ways. Firstly, the descriptions generated by the explanatory framework in section 7.1, were integral to the assessment of the broad conceptualisation and multi-tiered typology in subsections 7.3.1 and 7.3.2 respectively and hence I argue this supports the claim that the explanatory framework can be used as a tool to assess these conceptual proposals. Secondly, the descriptions generated by the explanatory framework, which were shown to be fit for purpose in section 7.1, were used in analysis of why and in what context particular phenomena might be considered emergent and in comparison of key characteristics related to emergence. This, I contend, supports the claim that the explanatory framework can be used to develop coherent descriptions of emergents which can then be used in analytical discourse to improve understanding of emergence.

The preceding analysis may also be used to further confidence in the form and coverage of the explanatory framework. Firstly, Table 7-24, p256 columns 3, 5, 7, 9, 11 & 13 illustrate the variation by which the differing key characteristics pertaining to the seven example emergents are realised and the '( )' illustrate the number of epistemological caveats that must be specified if we are to discuss the characteristics. For example, column 7 illustrates that macro-level causal powers may be the result of a sum or product of those of its component parts or indeed at present irreducible. This lends considerable weight to the design of the explanatory framework as it strongly supports the need to drill down regarding what exactly is meant by a key characteristic and why it might be interpreted differently due to epistemological perspectives. Secondly, as Table 7-25, p259 illustrates, non-simple ontological factors play a part in examples (c) – (g). This illustrates the need to explain not just the component parts but the complexities of how they are related. As such considerations are not part of all conceptualisations of emergence, this again lends further weight to the design of the explanatory framework as it strongly supports the advantages of a conceptualisation neutral approach to describing emergents.

Two issues that may limit the strength of the conclusions that may be drawn regarding the profitability of the explanatory framework can be identified. Firstly, as discussed in relation to the limitations of the analysis regarding the broad conceptualisation and multi-tiered typology, the descriptions and subsequent analysis upon which the usefulness of the explanatory framework is based are open to different interpretations depending on perspective. This has been minimised as much as possible and as discussed previously it does not irrevocably undermine the assessment of the profitability of the broad conceptualisation or multi-tiered typology. I would therefore argue that this does not compromise the usefulness of the explanatory framework. Indeed, I would suggest it indicates potentially profitable areas for further exploration in the quest to improve understanding of emergence.

Secondly, the preceding analysis, especially in subsection 7.3.2, was not solely based directly on the descriptions generated by the explanatory framework. For example, the loose matching of example emergents (c)-1, (f)-1,2 and (g) in Figure 7-8, p264 to *//Ontological_novelty/Macro_entity|rules/Hierarchies* was not based exclusively on the descriptions as the explanatory framework does not specifically investigate hierarchies. This does not compromise the conclusion that the descriptions can be used as a basis for assessing the multi-tiered typology as the descriptions are still used, just not exclusively. Further, it does not highlight a flaw in the descriptions as discussion of hierarchy was deliberately omitted in preference to the more holistic discussion of the emergence system as the evidence from the literature review of Chapter 2 and the discussion of Chapter 6, section

2.4.4 strongly suggest that a focus on hierarchies is somewhat limiting as emergents are in reality much more complex with multiple interconnections between non-global levels.

Thus, I argue, it can be concluded that the conceptual analysis of this section lends further support to the usefulness of the explanatory framework – the third conceptual proposal of this thesis.

To summarise, in this section conceptual analysis has been undertaken using the seven descriptions of real-world emergents developed in section 7.1 to further assess the profitability of the three conceptual proposals developed in this thesis. Firstly, the plausibility of the broad conceptualisation was further assessed through cross-analysis of the key characteristics. This illustrated that there are no common necessary and sufficient conditions for these emergents and thus supported the plausibility of emergence being a fuzzy concept. Next, cross-analysis of the descriptions illustrated that reference to characteristics relating to the three dimensions – ontological, epistemological and complexity – is necessary to adequately explain the emergent. Hence these two cross-analyses, I argued, further support criteria (i) and (ii) and hence the plausibility of the broad conceptualisation of emergence.

Secondly, the plausibility of the multi-tiered typology was further assessed by examining first its comparison and generalisation capabilities followed by its predictive and extrapolative capabilities. Comparison and generalisation was illustrated by loosely matching the example emergents of section 6.1 onto types/subtypes of the multi-tiered typology. These matches were then used to explain why and in what circumstances a particular example might be considered emergent. Next, it was 'predicted' which types/subtypes of the multi-tiered typology that emergents found within complex systems might be expected to match to. Analysis of sample emergents from a separate empirically study of learning communities confirmed the 'prediction'. Extrapolation was illustrated by identifying a set of characteristics common to a number of example emergents which all match a certain intersection of types/subtypes. Analysis of the sample emergents from the empirical study illustrated that they do indeed have the extrapolated characteristics. Hence these analyses, I argued, further support the profitability of the multi-tiered typology.

Finally, the profitability of the explanatory framework was addressed. As I had already illustrated that the descriptions of emergents that were developed using the explanatory framework were fit for purpose and as these descriptions were integral to analysis of the profitability of the broad conceptualisation and multi-tiered typology – a claimed key advantage of the explanatory framework – I argued that this supported the profitability of the explanatory framework. Further, I used additional consideration of the analyses to argue for the appropriateness of the form of the explanatory framework as well as its coverage.

None of the analyses were without limitations. The most significant was the inherent subjectivity of the analysis. However, this was minimised by recourse to additional 'form' information generated by the explanatory framework and by highlighting particularly subjective decisions. The sample size also means that statistical inferences are at best limited. As I have illustrated that these limitations have been minimised, I concluded that the analysis undertaken further confirmed the plausibility of the broad conceptualisation of emergence, the multi-tiered typology and the explanatory framework. Having completed the task of this chapter, the next section summarises the chapter developments and identifies the next and final stage of the research.

7.4 Summary and conclusions

This chapter has been concerned with conceptual analysis of the relationships between the various subconcepts relating to emergence and what the results might tell us regarding the profitability of the conceptual proposals of Part II. The first step undertaken was to develop neutral but conceptually relevant descriptions of seven real-world emergents which could be used as a basis for conceptual analysis. Before proceeding to use these descriptions, their fitness and limitations were examined. The descriptions were shown to improved clarity of areas which have previously been identified as problematic, although four potential issues were identified: difficulty in gathering sufficient information where scientific understanding of the phenomena is incomplete; lack of researcher domain expertise; difficulties establishing appropriate levels; and difficulties in ensuring consistency due to varying epistemological interpretations. As I argued, these issues do not affect the fitness of the descriptions as a basis for conceptual analysis provided that the contextual information contained within the description is borne in mind and that the descriptions are pragmatically revised when inconsistencies become apparent.

The conceptual analysis subsequently undertaken was designed to help assess the profitability of the broad conceptualisation and multi-tiered typology and as a result also to further assess the usefulness of the explanatory framework. The plausibility of the broad conceptualisation was further illustrated through two separate analyses. Firstly, cross-comparison of the range of key characteristics held by the differing examples, I argued, further supported the plausibility of the inherent fuzziness of emergence. Secondly, cross-comparison of the extent to which ontological, epistemological and complexity-related factors need to be taken into consideration in order to adequately describe the emergents, supported the claim that emergence has ontological, epistemological and complexity dimensions. Attention was then turned to further assessing the profitability of the multi-tiered typology. By loosely matching the seven descriptions of the example emergents using the multi-tiered typology, I showed it is possible to explain why and in what circumstances a particular example might be considered emergent, thus illustrating that the multi-tiered typology does indeed support comparison and generalisation. Further, the loose matching was then used to 'predict' where certain types of emergents might lie and to extrapolate expected characteristics. The characteristics of emergents within two learning communities were found to be in general agreement with these 'predictions', thus I argued, further supporting the claim that the multi-tiered typology supports prediction and extrapolation. As I had illustrated that the descriptions of emergents developed using the explanatory framework were fit for purpose and as these descriptions were integral to analysis of the profitability of the broad conceptualisation and multi-tiered typology, I further argued that this therefore lends weight to the profitability of the explanatory framework. Additional consideration of the analyses, I argued, could also be used to substantiate the rationale for the form of the explanatory framework as well as its coverage.

Thus, from the analysis of both classic and empirical examples presented in this chapter, I argue, it may be concluded that the three conceptual proposals of this thesis provide a profitable way to conceptualise and elaborate emergence as well to further understanding of real-world emergent phenomena. Thus, having answered the research questions – *SQ-E & SQ-RW* – in Chapter 4 - Chapter 6 through development of the three conceptual proposals – the broad conceptualisation of emergence, its elaboration through the multi-tiered typology and the complementary explanatory framework for developing neutral but conceptually relevant descriptions of emergents – and having now illustrated the profitability of these conceptual proposals through analysis, the remaining step is to assess the overall research process itself and examine where this work might lead. This is the subject of the next, and final, chapter.

Chapter 8 Summary and conclusions

The aim of this thesis was to investigate whether, given the wide variety of perceptions and conflict regarding emergence, a broad conceptualisation of emergence could lead to increased understanding.

This was achieved by first undertaking an extensive, interdisciplinary review of the existing body of work on emergence. This led to the identification of three main approaches which view emergence as ontological novelty, epistemological novelty and the product of a complex system respectively. *SQ-P – how might the claimed key characteristics, real-world examples and contradictions surrounding emergence be used to improve understanding of the concept* then informed further analysis of the extant literature. This revealed underlying conceptual and philosophical differences, language ambiguity, conceptual mismatches and not unsurprisingly a lack of agreement as to the 'essence' or key characteristics associated with emergence. However, the considerable body of discourse on emergence represents significant knowledge that can be built upon – the key problem therefore was how to profitably leverage this multiple disciplinary discourse to improve understanding of emergence. This led to adoption of a pragmatic interdisciplinary approach, the object of which was *to develop a broad conceptual framework which will act as an epistemological bridge, enabling researchers and practitioners from different disciplinary perspectives and philosophical stances to increase understanding of emergence within both interdisciplinary and disciplinary contexts (O).*This was achieved through three conceptual proposals. The first step was to introduce a brood conceptualisation of emergence which states that emergence may be profitably understood as (i) an inherently fuzzy concept, (ii) which is based around macro-level properties (emergents) which are not manifest in individual micro-level components in isolation and (iii) encompasses ontological, epistemological and complexity dimensions. Thus, *SQ-E – what is emergence* – was addressed. The next step was to further elaborate this potentially rich but unstructured conceptualisation so that it might be profitably used in conceptual analysis regarding emergence. Drawing on the multiple conceptualisations identified in the review, a multi-tiered typology of emergence was proposed which, it was argued, supports analytical interdisciplinary discourse regarding emergence. This parsimonious framework elaborates the broad conceptualisation of emergence. The multi-tiered typology further addresses *SQ-E?* The final conceptual development addressed how to improve understanding of emergent phenomena as opposed to the concept of emergence itself. This led to an explanatory framework designed to support development of 'neutral' but conceptually-relevant description of emergents, their causation and behaviour. It was designed to: assess how different epistemological factors might affect the description; capture the emergent and its causal environment; and to make explicit exactly what is meant by the key characteristics it identifies – key problem areas identified from consideration of why understanding of emergents is so difficult. Further, it was argued that the descriptions developed through the explanatory framework are phenomenon-grounded, independent of the broad conceptualisation and multi-tiered typology and thus may be used to independently assess their profitability. The explanatory framework addressed *SQ-RW – how might understanding of real-world emergent phenomena be improved.* The last but one task was therefore to apply the framework to seven classic putative examples of emergents. Examples from a separate empirical study of learning communities were also used to provide a degree of independent assessment. Analysis considered the explanatory descriptions of the emergents, the profitability of the broad conceptualisation and the analytical capabilities of the multi-tiered typology as well as the feasibility of the explanatory framework. The final task, and subject of this chapter, is to assess the extent to which the research summarised above has been successful in its objectives.

The chapter proceeds as follows. Firstly, the contributions of the research are discussed in section 8.1. This is followed, in section 8.2, by analysis of the success of the research and the approach that was adopted, followed by its limitations. Finally, future work arising from this research is discussed in section 8.3.

8.1 Contribution of the research

As has been discussed as the thesis progressed, the research offers several advantages, which, I argue, make a contribution to understanding of emergence and emergent phenomena. The contributions are highlighted below and their implications and relation to existing understanding are briefly discussed. In particular, what the development means for complex systems scientists, philosophers and practitioners interested in understanding and managing emergent phenomena is considered.

(a) Understanding the nature of emergence

A key contribution of this research is that it provides important novel insight into the nature of emergence. This is achieved by illustrating that emergence may be profitably understood as (i) an inherently fuzzy concept, (ii) which is based around macro-level properties (emergents) which are not manifest in individual micro-level components in isolation and (iii) encompasses ontological, epistemological and complexity dimensions. The key point here is that emergence may be profitably considered a fuzzy concept. This provides an important contribution to the ongoing debate as to the nature of emergence for two reasons.

Firstly, as was argued in Chapter 4, the broad conceptualisation offers a plausible explanation of why there have been such difficulties in developing a shared understanding of emergence. By this I mean the identification of the inherent fuzziness of the concept of emergence is a plausible reason why: as Holland (1998) observes, an ultimate definition of emergencies has proven problematic; as Roland et al observe, there will be debate regarding what to include as emergence; and as Kubik (2003) observes, definitions of emergence seem to overlap in some unclear way. This is because, as Wittgenstein (1954) observes, in the former case definitive definitions of fuzzy concepts are impossible and in the latter individual definitions or conceptualisations overlap without a common thread.

Secondly, this view of emergence moves understanding beyond a simple ontological-epistemological debate as to the nature of emergence. This does not suggest that the ontological status of emergence is not an important issue. What it does suggest though is that to fully understand the concept, we need to take into account how the concept developed, how differing views arise and how they are related. This is particularly relevant for a concept which first arose in response to observations that some phenomena appear to be intrinsically difficult to fully understand.

Thus, the view of the nature of emergence proposed in this thesis is important because it offers a reasonable explanation of the difficulties currently being encountered regarding the nature of emergence. Further, I argue, it makes sense given the multiple drivers for, and disciplines involved in, developing the concept.

This view of emergence has two important implications. Firstly, it suggests the quest for an ultimate universally accepted definition is likely to be unfruitful and is discussed further in subsection 8.1 (b). Secondly, this view of emergence provides a sound conceptual foundation for leveraging understanding of emergence across disciplines and philosophical stances.

The claim to novelty of this view of emergence, I would argue, is justified because while Kubik, Holland, Roland et al and others remark on the apparent inherent difficulties in defining exactly what emergence is and indeed describe problems or characteristics which suggest fuzziness, none of them directly consider inherent fuzziness or what that might tell us about the quest to improve understanding of emergence. The view of emergence as inherently fuzzy provides a plausible explanation for their observations, something which they failed to do, although it should be noted that this was never the aim of their work.

Some might argue that such a view of emergence is too broad to be of scientific or of real-world value. However, I would argue that without coherent conceptual foundation, the ability to effectively tackle scientific problems must be questioned. Without a coherent epistemological basis for any scientific deductions and explanations proffered, we are unlikely to be able to soundly leverage the potentially creative insights afforded by interdisciplinarity (Klein 1990).

Another counter argument might be that I have created the fuzziness by embracing the full range of discourse on emergence. However, not only do a variety of conceptualisations clearly exist, but there are clear difficulties in identifying agreed necessary and sufficient conditions for emergence. I would therefore suggest that failure to consider the full range of conceptualisations itself creates a somewhat limited and artificial conceptual landscape.

A clear advantage of this view of the nature of emergence is that it does not imply that other conceptualisations of emergence are wrong. Indeed, it is a core tenet of this research that these conceptualisations may be highly profitable within specific contexts. Rather, the broad conceptualisation offers, I argue, a way of understanding why these different conceptualisations exist and how they might be brought together to raise the level of understanding regarding emergence. Thus, it contributes new, coherent and, potentially useful understanding of the nature of emergence. Further, given the research approach that was adopted, there is no claim that this is an ultimate view as to the nature of emergence; rather the claim is the potential usefulness of the broad conceptualisation.

(b) Enables coherent interdisciplinary conceptual analysis regarding emergence

Another key contribution of this research is that it affords coherent and I would argue profitable interdisciplinary conceptual analysis regarding emergence. It achieves this through the multi-tiered typology which was shown in Chapter 5 and Chapter 7 to offer a means of supporting interdisciplinary communication and analysis regarding both the concept of emergence and real-world emergents. This ability to support coherent interdisciplinary conceptual analysis is, I would argue, an important contribution as it provides us with a method of leveraging different disciplinary knowledge. Successful leveraging of interdisciplinary knowledge depends on being able to constructively utilise disciplinary knowledge. As discussed in Chapter 3, section 3.1, without this it may simply be impossible to move forward given lack of common ground, or conceptual or scientific errors may be introduced. The multi-tiered typology surmounts these problems by providing a coherent way of linking locally consistent conceptualisations. This facilitates the inclusion of internally consistent discipline-specific concepts and offers a conceptual path between these different components. It thus offers a plausible way of moving beyond simple interdisciplinary borrowing of concepts from a different discipline, enabling the different perspectives to be brought together to support analysis of the complex problem of what constitutes emergence. Thus, it combines the advantages of borrowing and interdisciplinary problem solving while providing a mechanism to overcome the pitfalls associated with diverse thought domains.

The multi-tiered typology, I suggest, provides a novel way of achieving this. This is because, while typologies have already been developed within the discourse on emergence, they have in general not been concerned with conceptual analysis but rather with classification of types of emergence. The exception are Stephan's (1992) typology which analyses conceptualisations and Silberstein's (2002) typology which analyses the philosophical status of approaches to emergence in terms of an ontological-epistemological divide. However, as argued earlier, these typologies do not capture overlaps in conceptualisation. It is, I have argued, the overlap of key characteristics that enables more detailed conceptual analysis of the nature of emergence and how emergent phenomena might best be understood.

It might be argued that conceptual analysis will not bring with it the same benefit as scientific investigation. However, the focus on interdisciplinary analysis is not intended to replace all scientific analysis of emergence. Rather, as argued previously, it is about leveraging extant knowledge in a coherent way. The choice of using an idealised type typology to support the conceptual analysis might also be challenged. For example, the existing discourse could simply be used directly. However, as I have argued in Chapter 5, its advantage is that it offers a coherent and parsimonious framework. Further, a more scientific modelling approach is inappropriate for conceptual analysis and, given the current diversity of conceptualisations, it is likely to either be too broad to support any interesting investigation or fail to encompass the diversity.

As the literature review illustrates, a significant body of conceptual analysis regarding emergence has already been undertaken. Further, we are beginning to see the introduction of non-linear dynamical systems into philosophical discussions of emergence (Bedau 1997, Bedau 2002, Collier and Muller 1998). The method of interdisciplinary conceptual analysis proposed in this thesis, I argue, goes significantly beyond these approaches as it embraces the differing ontological, epistemological and complex systems perspectives rather than choosing a preferred ontological or epistemological perspective. It is therefore, I argue, more likely to be able to support reasoned considerations of how these different factors relate to emergence.

(c) A means of developing shared meaning regarding emergence

Another contribution is that the conceptual developments provide a sound basis for the development of shared meaning regarding emergence and emergents. Lack of shared meaning has been particularly problematic within discourse on emergence as the number of approaches and conflicts identified in the literature review of Chapter 2 illustrate. In particular, this lack of ability to effectively describe emergence and emergents within a generally accepted normative usage has, I have argued, restricted the ability to effectively leverage different disciplinary and philosophical ideas, and led to very idealised proposals which do not then realistically capture the real-world processes and phenomena that gave rise to the concept of emergence in the first place. Thus, any tool or understanding that reduces these problems is to be welcomed. As discussed in Chapter 5, development of shared meaning is plausibly facilitated through the multi-tiered typology as it provides both an elaboration of the differing conceptualisations and a means of specifying how and when they are applied – i.e. it describes differing normative usage and the 'cultural' use of their application.

To be clear, I am not advocating here that one unique meaning of emergence can or indeed should be developed. As Wittgenstein (1954) first identified, one consequence of a fuzzy nature is that a unified shared meaning of emergence will be out of reach. The contribution here is a method of facilitating shared meaning within a particular context. Indeed, the bringing to the surface of the realisation that a generalised explicit definition is impossible is, I contend, a further useful contribution to knowledge. In particular, it will allow investigation to be focussed on more achievable tasks.

Such an ability to facilitate shared meaning within a given context is important. As I have argued in several places, this thesis is not principally concerned with conceptual borrowing, but rather with interdisciplinary problem solving. Thus, we need to be clear what the problem is – what particular aspect of emergence is being addressed. This is particularly important in practitioner enquires as they are not interested in conceptual nuances but rather how they can practically improve understanding and management of real-world emergent phenomena. In order to be able to achieve this, being able to clearly identify what is being discussed between differing thought domains in a normative rather than in an abstract or idealised way is important.

(d) Focus on emergence system as opposed to physical determination

A more preliminary contribution, but one which I would suggest may potentially open up new insight and approaches is the consideration of the base upon which emergents are determined in terms of an emergent system. The emergence system embraces non-linear physical and epistemological causes as opposed to simple consideration of micro-level components upon which the macro-level emergent is physically determined. This is a core feature of the explanatory framework proposed in Chapter 6. This contribution is, to a large extent, more tool-like rather than a contribution to new knowledge as it provides a framework for bringing together varying causal considerations which are in the main already recognised. However, as I have argued in Chapter 6, it is a potentially useful framework as it focuses consideration on the complex interaction of ontological and epistemological causes – the key forms of causal factors identified in the extensive literature review. In particular, it brings together complex systems and the varying philosophical considerations in a more coherent way. While there has recently been a move towards combining ontological and complex systems approaches (Bedau 2002, Collier and Muller 1998, Bar-Yam 2004, Ryan 2006), these do not generally include consideration of epistemological aspects. Given that the concept of emergence arose from perceived difficulties in explaining macro-level phenomenon, I would argue that how we understand phenomena is an important part of any considerations. Thus, any framework that encourages us to take not only ontology and complexity into account but also how we understand the system should aid clarity.

It might be argued by some that, assuming non-vitalism, all epistemological causes are mere epiphenomena and therefore consideration of the physical base is sufficient. However, that does not really help with practical understanding of emergents, as non-linear dynamics mean that information is lost over time and thus epistemological causes may not be reducible in practice to physical causes. Thus, rather than being dismissed as mere epiphenomena, epistemological causes can potentially be viewed as a valuable conceptual tool – a token, if you will, which lets us consider missing information and its consequences.

A particular innovation is the inclusion of internal (i.e. ontological) subjectivity as a potential cause. As discussed in Chapter 6, this draws on Crutchfield (1994), Shalizi (2001) and Pattee (2000) who, in differing ways, consider how a system might potentially capitalise on its internal structure. This, in my opinion, is an area that has been considerably under researched within emergence discourse. By specifically including subjectivity within causal considerations of a system I suggest we may be able to shed new light on internal subjectivity – a feature which is to be found throughout 'higher levels' such as the biosphere, language and human society.

Others may question the inclusion of 'ontological subjectivity', suggesting it is adequately covered by, for example, Bar-Yam's (2004) micro, macro (system) and environmental constraints. However, as I have argued again in Chapter 6, it is useful as it highlights something which we do not yet completely understand. It may be that it can be adequately covered by other means, but in the meantime it focuses attention on heterogeneity and organisational structure of the system in which emergents arise. This is something which, as I will discuss below in section 8.3, is potentially a fruitful area of future research if we want to be able more fully to understand the causes and behaviour of real-world emergent phenomena. It could be argued that subjectivity is related to change rather than emergence. However, as characteristics such as functionality or symbolism, all of which have an element of system subjectivity, seem to be common at 'higher levels' such as the biosphere, language, human society then, I argue, we should at least consider them in our exploration of emergence.

(e) A conceptual scaffold for improving understanding of emergence and emergents

The final contribution highlighted here is that the conceptual developments – the broad conceptualisation, multi-tiered typology and explanatory framework – together form a conceptual scaffold for improving understanding of emergence. Conceptual scaffolds can be thought of as tools, strategies and guides which support the development of higher levels of understanding which could not normally be achieved without additional assistance and have been of particular interest within learning (Vygotsky 1978). The set of conceptual developments presented within this thesis, I would argue, does precisely this. For example, I have illustrated within the preceding chapters that the conceptual proposals offer a means of organising, analysing, synthesising, and evaluating emergent phenomena – exactly the functionality that Means (1994, cited in Brush and Saye 2002) associates with conceptual scaffolding used within learning.

What is a key feature of the conceptual development and an essential part of conceptual scaffolding according to Vygotsky (1978) is that it supports reflective discovery. By this I mean that the conceptual developments do not simply provide a turnkey approach to understanding emergence; their use require some reflective effort. However, I suggest as a result of the reflection process they may be more powerful than a simple formulaic approach. This is because as I have argued throughout this thesis, as emergence is concerned with macro-level phenomena that are difficult to explain in terms of their component parts, we cannot ignore the role of how we explore and understand such features. Reflection is required.

While some might argue that conceptual scaffolding is irrelevant, I would argue that the type of reflective discovery that conceptual scaffolding provides is highly important with respect to emergence for two reasons. (i) Given the differing disciplinary and phenomena contexts, it is unreasonable to expect an ultimate method of explaining emergence or emergents. Rather, each context must be considered as a whole through reflection regarding the appropriate factors. (ii) As emergence is increasingly recognised as being of practical engineering and social interest and not just of scientific or philosophical interest, there will be an increase in practitioner interest in the concept. Here it will be imperative that practitioners are supported as much as possible in developing understanding without the need for recourse to scientific or philosophical experts. Thus, the implications of the set of conceptual tools developed in this thesis extend beyond the philosophical or scientific domain.

In summary, this section has discussed five contributions that the research makes to the discourse on emergence. These relate to: understanding the nature of emergence; enabling coherent interdisciplinary conceptual analysis; developing shared context-specific meaning of emergence; understanding emergence in terms of a complex causal system as opposed to a purely physical base; and provision of a conceptual scaffold for improving understanding of emergence.

8.2 Assessment of the research

Having discussed the contributions of the research, the success of the research – whether it achieved what it set out to do – and of the research approach – whether it was fit for purpose – are considered in this section.

8.2.1 Success of the research

The research was concerned with improving understanding of emergence, specifically, the overarching research question was – *Can a broad conceptualisation of emergence lead to increased understanding of emergence?* As the research adopted a pragmatic and interdisciplinary research strategy with conceptual analysis as its key analytical method, assessing the success of the research – whether the broad conceptualisation and related conceptual developments led to improved understanding – presents some difficulties. As discussed in Chapter 3, subsection 3.2.3(d), such a research strategy is concerned with profitability – plausibility and potential usefulness – rather than developing a definitive theory of what emergence is. Usefulness, I argued, not only refers to whether it has practical application but also equally importantly, whether it can shed new light on some problems which have to date resisted inquiry. As usefulness is arguably best assessed with regard to purpose, translating these general criteria to the specific context of interdisciplinary discourse on emergence, as Table 3-5, p 133 summarised, I contended that the broad conceptualisation and related conceptual developments might reasonably be said to be useful if they: (i) provide a coherent and plausible description of the broad concept of emergence; (ii) provide an explanation of at least one key conflict surrounding understanding of emergence; (iii) facilitate disciplinary and interdisciplinary analytical discussion regarding emergence. Using these criteria, whether the research can reasonably be judged as successful is considered below.

Firstly, the broad conceptualisation and its elaboration offers a profitable description of what emergence is. Plausibility of the description and its elaboration was illustrated in Chapter 4 and Chapter 5. As it was then argued in Chapter 5 that it can be used to support interdisciplinary communication regarding what is meant by emergence and that it is compatible with normative disciplinary usage of the concept, I contend that it is reasonable to consider the description useful within the context of interdisciplinary research. In particular, as discussed in section 8.1(a) & 8.1(b) above, a specific contribution is that it manages to bring together existing differing disciplinary and philosophical stances in a coherent way.

Secondly, returning to the conflicts discussed in the literature review of Chapter 2, the broad conceptualisation of emergence and its associated conceptual developments arguably can be said to shed new light on three of the conflicts. (1) As discussed in section 8.1(a) above, it both sheds new light on the nature of emergence and provides a plausible explanation of why there have been such conflicting views as to its nature. (2) As discussed in section 8.1(c), it provides plausible reasons why the quest for an ultimate general definition of emergence has proven so difficult and is ultimately unlikely to be achievable. (3) As discussed in sections 8.1(a) & 8.1(d), it illustrates that it may be more useful to view emergence as a complex product of ontological and epistemological causes, rather than debate whether it is ontological or epistemological in nature.

Finally, the broad conceptualisation and its elaboration through the multi-tiered typology support coherent interdisciplinary conceptual analysis regarding emergence. The plausibility of this was illustrated in Chapter 5 and its practical application was illustrated in Chapter 7. As discussed in section 8.1(b) above, I suggest this is particularly useful as coherent conceptual analysis is difficult to achieve within an interdisciplinary context.

Thus, by the above criteria, I would contend that the research can reasonably be judged as successful. Further, the sub-research questions were also successfully addressed. SQ-E, which was concerned with the nature of emergence, was dealt with through the broad conceptualisation and its elaboration via the multi-tiered typology. *SQ-RW*, which was concerned with how understanding of emergent phenomena might be improved, was addressed through the explanatory framework. Having justified the claim to success of the research, the success of the research approach together with *SQ-P*, which was more concerned with methods, are considered next.

8.2.2 Reflections on the research approach

The general research approach employed a combination of pragmatic, interdisciplinary and conceptual analysis strategies. The rationale for each of the research strategies is briefly summarised below followed by a discussion of how it was implemented within the research, including any difficulties that arose. Key issues which might affect the fitness of the strategy and impact the research which were identified in subsection 3.2.3(d) and summarised Table 3-6, p134 are then considered. The choice of particular methods within the research strategies is not considered here as these have already been discussed within the core body of this thesis. This, then, leads to an assessment of the overall fitness of the strategy.

(a) Pragmatic strategy

The rationale for the pragmatic strategy derived from *SQ-P – how might the claimed key characteristics, real-world examples and contradictions surrounding emergence be used to improve understanding of the concept*? If these differences and conflicts were to be used as a starting point for evolving understanding then a degree of pragmatism was required.

As discussed in Chapter 3, the pragmatic strategy was implemented by: (i) adopting and critically analysing the wider conceptualisations and an extensive example set of putative emergence; (ii) discarding those which prove unpractical; and (iii) making explicit under which contexts any insights hold. All three parts of the strategy are clearly in evidence throughout the thesis. For example, the review of Chapter 2 clearly critically analyses a wide variety of conceptualisations and putative examples are used throughout the thesis. Further, a key function of the typology is to help make explicit when particular conceptualisations and their characteristics are the subject of discussion.

One potential issue with a pragmatic approach is ensuring that sufficient substance is achieved. By this I mean that if the approach is not sufficiently focused on the goal it is trying to achieve and how the various steps taken affect validity then revision of the research process and concepts as the research proceeds may seriously affect the validity of the results. Thus, before dismissing and revising attempts, careful consideration of the implications for the validity of the research was undertaken. For example, the set of conceptualisations of Chapter 2, subsection 2.3.2 that relate to model change where at the outset grouped into a separate set. However, after more detailed consideration these were grouped under epistemological novelty as presented in Chapter 2, subsection 2.3.2. As these changes were made before any detailed analysis work was carried out, there was no implication for validity in this refinement. Further, as has been noted within this thesis, some related research has been undertaken which is not presented here for size and coherence reasons[72]. Before the decision not to include this work in full was taken, the various steps were carefully analysed to make sure there were no hidden interrelations that might compromise the validity of what is presented here. The most significant potential problem in doing this was the inclusion of subjectivity in the explanatory framework. This has, to a degree, been 'borrowed' from this related work. However, after careful consideration, I contend that this stands sufficiently on the argument presented here for inclusion. Indeed, it was felt that its removal would reduce the completeness of the explanatory framework and its assessment.

The choice of examples and conflicts upon which to base the research will also clearly affect the research outcomes. Here, the important point is to choose examples and conflicts which

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[72] The related research is not incoherent; rather to include it satisfactorily would have: (i) doubled the size of the thesis and (ii) diluted the focus and depth of argument that could be offered within the limits of a PhD thesis.

sufficiently span the domain under investigation. Choice of examples and counter examples was particularly challenging given the fact that there is lack of agreement regarding claims to emergence. As discussed in subsection 3.2.1, examples were primarily selected by considering whether they were a driver for study of emergence as in the case of the mind or life, illustrative of particular disputes regarding claims to emergence as in the case of thermodynamics or the smell of ammonia or illustrative of particular putative key characteristics. However, a much wider base than has been presented here was initially used. Thus, the examples and counter examples that are actually presented in the thesis are selected with the benefit of hindsight – they represent either particular interesting cases or typical examples. Clearly it is difficult to assess whether an interesting case has been missed. The extensive literature survey instils a reasonable degree of confidence that key known interesting cases have been considered, but it must be accepted that: (i) different interesting cases may yet be identified or (ii) others may have a differing view on what is interesting. Ensuring that the problem domain was sufficiently spanned was not so vital because, as discussed in section 3.1, the intention was not to solve all problems, but rather to make inroads. However, it must be acknowledge that the particular choice of conflicts upon which to focus dictated the research direction.

Thus, as the potential issues associated with a pragmatic strategy (summarised in Table 3-6, p134) have been minimised or are irrelevant and as the research has managed to successfully utilise the conflicts, differences and putative examples to develop the broad conceptualisation, multi-tiered typology and explanatory framework, all of which, it has been argued in section 8.1, afford new insight and understanding regarding emergence, then I would contend that the pragmatic strategy has been successful. Further, as the pragmatic strategy was derived from *SQ-P – how might the claimed key characteristics, real-world examples and contradictions surrounding emergence be used to improve understanding of the concept* – the research methods employed addressed *SQ-P*. For example, the claimed key characteristics were used to focus research as well as playing integral roles in the multi-tiered typology and explanatory framework. Real-world examples were continually used to expose issues, further explain meaning and to test the conceptual developments. Finally, as discussed above the contradictions played a significant role in focussing the conceptual developments.

(b) Interdisciplinary strategy

As discussed in section 3.1, the decision to investigate whether a broad conceptualisation of emergence could improve understanding strongly suggested that an interdisciplinary approach was required, given the wide range of extant discourse on emergence, spanning several quite different disciplines. A variation of the 'problem solving' form of interdisciplinary approach was chosen[73] where (i) the problem was a conceptual one rather than the typical real-world problems and (ii) interdisciplinary conceptual analysis was the new 'method' to be developed to resolve the complex problem of understanding emergence.

Different disciplines and thought domains were brought to bear in a variety of ways. Firstly, the literature research covered a range of disciplines interested in emergence – most significant were philosophy and complex systems. However, biology, social sciences, physics, chemistry and computing science were all included to some extent through consideration of classic examples of emergent phenomena. Indeed, complex systems is arguably interdisciplinary itself. Secondly, methods and ideas were utilised from philosophy and complex systems, although there was significant use of basic mathematical ideas to conceptualise the problems and solutions as that is my original disciplinary background. So for example, the coherence and local consistency of the conceptual space associated with the multi-tiered typology was originally conceived of in terms of metaphors such as the structure and continuity of a topographical space. Thirdly, the conceptual developments were specifically designed to support interdisciplinary discourse through development of an epistemological framework which provided transdisciplinary bridge. As discussed in Chapter 4, the broad conceptualisation provides the transdisciplinary bridge and, as discussed in Chapter 5, the structure of the multi-tiered typology supports interdisciplinary discourse.

The biggest potential issue with the interdisciplinary strategy is that in a PhD there is only a single researcher. Thus, much of the claim to interdisciplinary input came from use of extensive extant literature on emergence covering a range of disciplines. However, as I myself have an interdisciplinary background moving from an original disciplinary grounding in mathematics and physics through computing science to a more recent research interest in complex socio-technical systems, significant direct insight from multiple disciplines can also be reasonably claimed. Thus, within the confines of PhD research, a reasonably claim to interdisciplinary research, I would contend, can be made.

Another potential issue is that disciplinary norms, methods and shared language cannot be relied upon (Wear 1999), potentially leading to unsound conclusions. However, as discussed

[73] The research therefore also makes a contribution to interdisciplinary research methods.

in section 3.1, the research used this issue to focus developments. For example, the multi-tiered typology is specifically designed to surmount this problem. Thus, in this research, I would argue that the potential disadvantage of interdisciplinary discourse has been turned on its head, leading to significant insight into how emergence might be profitably understood.

Thus, as the potential issues associated with interdisciplinary research (summarised in Table 3-6, p134) have been reduced and as the research has managed to successfully develop a broad conceptualisation of emergence and related conceptual tools that it has been argued offer a plausible and potentially useful new understanding of emergence, I would contend that the interdisciplinary strategy has been successful. I would further contend that given the stated aim of leveraging extant disciplinary knowledge, an interdisciplinary strategy was necessary.

(c) Conceptual analysis

The aim of this thesis was not to resolve the extremely hard problem of what emergence is; rather it was to make useful, practical inroads into a very difficult problem – the nature of emergence. As discussed in section 3.1, the decision to focus on interdisciplinary conceptual problem solving to improve understanding of the nature of emergence led to undertaking a significant element of conceptual analysis.

The conceptual analysis undertaken consisted of breaking down the concept of emergence into component parts – the different conceptualisations and their key characteristics. By doing this, it was then possible to develop a coherent elaboration of the broad conceptualisation through the multi-tiered typology. As illustrated in Chapter 5 and Chapter 7, this then enables further conceptual analysis regarding emergence to be supported. Thus, the two aspects of conceptual analysis – breaking down of the concept into component parts in order to rebuild a more coherent picture (Beaney 2008) were covered. Further, the research not only implemented a conceptual analysis strategy, as highlighted in section 8.1(b) above it also contributes a conceptual structure which supports further interdisciplinary analysis.

As discussed in 3.2.3(d), the principal limitation of conceptual analysis is that its outputs are not provable. Rather the best that can be said is that they are plausible and potentially useful. Conceptual analysis depends very much on the underlying philosophical stances and perceptions of the researcher. While every effort has been made to consider emergence from different philosophical stances and to minimise researcher bias, it would be impossible to limit this fully. This limitation must simply be acknowledged, but I would argue it does not diminish the benefits of the research which exposes plausible interpretations which have been shown to provide a reasonable explanation of some key issues. Further, it is a given of philosophy that there is always differing opinions regarding particular views or conceptualisations. This is an issue that cannot be minimised. Instead it must be made explicit, so that it is clear what the claims regarding the conceptual proposals actually are. Thus, as long as it is acknowledge that the conceptual proposals presented here are not ultimate truths but rather offer plausible and potentially useful ways of considering emergence – which has been clearly emphasised throughout the thesis – then this does not compromise fitness of the conceptual proposals.

While it might be argued by some that a more scientific approach would have led to firmer results, as I argued in section 3.1, given the current state of understanding regarding emergence it is unlikely that such an approach would provide a universally acceptable and complete understanding of emergence. Further, I would suggest, given the interrelated ontological and epistemological factors which, I have argued, affect both emergents and our conceptualisation of emergence, the ability to develop a definitive theory of emergence in the future must be at least questioned.

Thus, as the potential limitations associated with conceptual analysis have been made explicit and as the research has managed to successfully develop a *broad conceptual framework which acts as an epistemological bridge, enabling researchers and practitioners from different disciplinary perspectives and philosophical stances to increase understanding of emergence within both interdisciplinary and disciplinary contexts (O)* which, it has been argued, offers a plausible and potentially useful new understanding of emergence, I would contend that the pragmatic interdisciplinary conceptual analysis strategy has been successful.

(d) Conclusions and reflections regarding the research approach

To conclude, the research made significant use of all three research strategies, each of which, I have argued, can reasonably be considered to be successful. In combining these strategies, each of which has been chosen directly by the needs of the research, I have followed Patton's (2002) advice of favouring methodological appropriateness in preference to a more orthodox single research strategy. A narrower research strategy, I would contend, simply would not have been able to achieve what this combination has done, as it would not have met the diverse methodological needs of this research. However, care is required when using such an approach. Thus, in developing each aspect of the overall research the implications and limitations of the differing research strategies have also been considered. So for example, in subsection 3.2.2(b), the implications and limitations of interdisciplinarity feature heavily in the discussions of how to best elaborate the broad conceptualisation of emergence.

Considerable time was spent early in the research process exploring other possible strategies. In particular, whether empirical work could be reasonably undertaken was considered. In the end, the judgement was to focus on conceptual development with limited practical work to assess the conceptual proposals. This, I would argue, enabled much more conceptual depth to be explored within the limited space of a PhD thesis. More detailed testing is another project.

Given, the preceding discussions of the research approach and that it was argued that the research might reasonably be viewed as successful, I would contend that it is reasonable to conclude the research strategy too has been successful.

In summary, in this section I have argued that both the research and the research approach may be reasonably considered successful. Next, future work is considered.

8.3 Future Work

The next step is to publish the work presented in this thesis to expose the research to further peer review and, as a result, to assess the extent to which the ideas presented here can offer conceptual and practical help to researchers and practitioners alike[74]. This exposure should help elicit particular areas where the research may be potentially of most value. High profile research and practitioner publications will be targeted, as well as community forums such as EmergeNET. However, some potentially profitable areas of work can be identified at present. This future work can be categorised into two aspects: further assessment of the conceptual proposals and exploration of emergence using the proposals as a conceptual scaffold. Each of these is discussed in turn below.

Further assessment of the conceptual developments

Two pieces of work might be undertaken to further assess the profitability of the conceptual proposals. Firstly, whether emergence is a fuzzy concept might be assessed using empirical

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[74] Some very early work has been presented McDonald and McGill (2005), McDonald and Weir (2005). The research presented here however has significantly evolved from these early considerations.

testing of how individuals categorise emergence. This could draw on the likes of Rosch's (1973, 1975) work on investigating how categories arise and are structured internally in human minds. Secondly, the usefulness of the multi-tiered typology and descriptive framework could be further assessed by determining its applicability within both interdisciplinary research and practitioner teams.

Exploration of emergence using the proposals as a conceptual scaffold

The broad conceptualisation, multi-tiered typology and explanatory framework presented in this research might be used as a conceptual scaffold to investigate appropriate tools and relationships. For example, the conceptual proposals might be used to explore what are the most profitable conceptualisations for particular groups of emergents or whether there are key underlying relationships between key characteristics which might indicate similar causal processes at work. Additionally, the conceptual scaffolding might be used to investigate key conflicts and problems surrounding understanding of emergence.

Further, while scientific explorations are valuable, in my opinion, there needs to be much more analytical work carried out into how we understand emergence and emergents. The conceptual scaffolding may be used to undertake such work. For example, the role of epistemology in the causal system associated with emergence, I would suggest, is an area that is worth further study. While considerable philosophical work has been carried out, this has tended to be associated with establishing the underlying ontology of emergence. In such analysis, the observer tends to be disassociated from the system in which emergence arises. While in many cases this may be a reasonable approach, in some cases such as biology and social systems or, as argued in Chapter 7, even in the case of thermodynamics, this may fail to adequately capture the situation. While some might argue that apparent epistemological causes are mere epiphenomena, I would strongly argue that if we are concerned with novelty and understanding, simply to dismiss features as epiphenomena is not helpful. The macro-level emergents may offer better explanations of observations and therefore, I would suggest, should be considered more thoroughly rather than simply dismissed. Study of such issues, I would suggest, may offer a profitable path to move from conceptual analysis to explication of some of these problematic areas associate with emergence.

Two areas, I would suggest, might offer a profitable focus for such research – information systems and innovation systems. Information systems are particularly interesting as we are moving away from a traditional linear input-output paradigm to interactive computing (Wegner 1998, van Leeuwen and Wiedermann 2001). In interactive computing, human intervention changes the information system as computation activities are ongoing. The World Wide Web and its various layers of information and social networks is perhaps the iconic example of this. We cannot hope to understand the emergence which occurs in such systems without taking epistemological factors into account. Given the current pervasiveness of the Web in educational, business and social fields, I would suggest this is a prime area for further research. Innovation systems, arguably, are another key area where emergence of new knowledge, practices and inventions depend significantly on cognitive capabilities and hence epistemological causes of those involved. However, the underlying structure of the system that supports it is also key, with current discussions focussing on open innovation models (Chesborough 2003).Thus, both 'systems' are highly creative, with novel macro-level phenomena arising from a complex interaction of ontology and epistemology. Improved understanding of the epistemological causal role would benefit researchers and practitioners alike.

Further, as has been mentioned in several places in the thesis, the role of subjectivity, or more generally the organisational structure of the emergence system, warrants further investigation. As organisational features can be thought of as parts of the organisation which is frozen in time, identification of different types of organisational features may aid understanding of causality within the system. This is to an extent what Jones' (2002) typology sets out to do. However, the types of relationships it identifies are quite simplistic. When the most complicated is simply described as "'Mutualistic' feedback relations", this feels slightly like consigning what is happening to a black box. More detailed exploration of the organisation of the system, I would suggest, has the potential to greatly improve understanding of real emergence systems. This, I suggest, would require an extension of the conceptual proposals to include organisational components such as functionality or memory – just some of the key organisational features we see in biological and social systems. Some initial work in this area has already been carried out in parallel to this research and interim results can be found in McDonald and Weir (2005, 2006). More extensive work is yet to be undertaken. The domain of consideration to date has been learning communities, but I would suggest the information systems and innovations systems would again also be interesting areas in which to set this work. Further, such work would be of potential benefit to both those trying to understand the system and to practitioners as they refine interventions that seek to manage emergence.

Appendix A Cross-analysis of example emergents

Example emergents \ Meta-relational properties	Surprise	Predictability	Scope	Resolution	Reducibility	Scope	Resolution
(a) Property being a circle	×	RP	×	×	S	×	×
(b)-1 Temp.	×	RP	×	×	S+	×	(✓)
(b)-2 Entropy	✓	RP	×	×	S+	×	(✓)
(c)-1 Properties of ammonia	×	RP	×	×	P	×	×
(c)-2 Realisation of smell of ammonia	×	IP/(U)	×/(✓)	×	CP/(I)	×/(✓)	×
(d)-1 Characteristics of a machine	×	RP	×	×	P	×	×
(d)-2 Planned Functionality of a machine	×	RP	×	×	CP+	×	×
(d)-3 Unplanned Functionality of machine	✓	IP/U	(✓)	(✓)	CP/(I)	(✓)	(✓)
(e)-1 The Web	(✓)	IP	×	×	CP	×	×
(e)-2 Structure of the Web	✓	IP	×	(✓)	CP	×	×
(f)-1Abiogenesis	×	IP	×	(✓)	CP	×	×
(f)-2 Biological life	×	IP	×	(✓)	CP	×	×
(g) Metacognitive properties	×	U/IP	×	(✓)	I/(CP)	×	(✓)

Table A-1: Cross-comparison of meta-relational properties of examples of section 7.1

Example emergents \ Generators	Component	Macro	Relational	Self-org	Manufacture	Design	Prior E	subjectivity	Observation	reason	Scope	Resolution
(a) Property being a circle	×	✓	×	×	✓	✓	×	×	×	×	×	x
(b)-1 Temp.	×	×	×	×	×	×	×	×	✓	×	×	×
(b)-2 Entropy	×	×	×	×	×	×	×	×	×	✓	×	×
(c)-1 Properties of ammonia	✓	×	×	✓	×	×	×	×	×	×	×	×
(c)-2 Realisation of smell of ammonia	✓	×	✓	✓	×	×	✓	✓	✓	×	×	×
(d)-1 Characteristics of a machine	✓	✓	×	×	✓	✓	(✓)	(✓)	(✓)	(✓)	×	(✓)
(d)-2 Planned Functionality of a machine	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	×
(d)-3 Unplanned Functionality of machine	✓	×	✓	✓	✓	×	✓	✓	✓	✓	(✓)	(✓)
(e)-1 The Web	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	×	×
(e)-2 Structure of the Web	✓	(✓)	×	✓	✓	×	(×)	(×)	✓	✓	✓	×
(f)-1Abiogenesis	✓	✓	✓	✓	×	×	✓	✓	×	×	×	(✓)
(f)-2 Biological life	✓	✓	✓	✓	×	×	✓	✓	×	×	×	×
(g) Metacognitive properties	✓	?	✓	✓	×	×	✓	(✓)	?	-	×	(✓)

Table A-2: Cross-comparison of generation properties of examples of section 7.1

Example emergents \ Causal Power	Macro-level	Scope	Resolution	DC	Scope	Resolution
(a) Property being a circle	×	×	×	×	×	×
(b)-1 Temp.	S	×	×	×	×	×
(b)-2 Entropy	(I)	×	(✓)	×	×	×
(c)-1 Properties of ammonia	P	×	×	×	×	×
(c)-2 Realisation of smell of ammonia	P	×	×	×	×	×
(d)-1 Characteristics of a machine	P	×	×	×	×	×
(d)-2 Planned Functionality of a machine	(P)	×	(✓)	×	×	×
(d)-3 Unplanned Functionality of machine	(P)	×	(✓)	×	×	×
(e)-1 The Web	CP	×	×	Co	×	×
(e)-2 Structure of the Web	P	×	×	At	×	×
(f)-1Abiogenesis	CP	×	×	Co	×	×
(f)-2 Biological life	CP	×	×	Co	×	×
(g) Metacognitive properties	(I)	×	(✓)	(I)	(✓)	(✓)

Table A-3: Cross-comparison of causal power properties of examples of section 7.1

Appendix B Emergence in Learning Communities

This appendix contains details regarding emergence found in two empirical case studies which investigated emergence in learning communities as part of a separate project to this thesis. The case studies are briefly introduced below and further details can be found in McDonald (2005), McDonald and Weir (2006)[75].

The first case study - DIDET[76] – concerns a learning community which grew out of a cross-disciplinary, cross-institutional, UK-US collaborative project to develop and trial methods to capture and reuse tacit knowledge within a higher educational and research context. The purpose of the collaborative partnership, which commenced in 2002 between a Higher Educational Institute (HEI) in the UK and a partner HEI in the US, was to explore the use of digital libraries to support global team working within design engineering. This resulted in a core project learning community of students, academics and support staff spanning both the UK and US partner HEIs. Both HEIs have built on considerable previous experience in supporting learning and research within design engineering and while the project was not about building technology per se, in reality the development of technology to support the day to day working practices and the capturing of tacit knowledge produced has been a major part of the project along with analysis of its effects, development of good practice and dissemination of the lessons learned.

The second case study was centred on the learning community which developed around the REAL Partnership[77]. The REAL learning community grew from an initial partnership agreement in 1999 between the Local Development Agency (LDA), the city council and the local Further Education (FE) and Higher Education (HE) institutions, with the aim of building a learning city within a large post-industrial city to improve the employment profile and general well-being of its citizens and to aid the economic regeneration of the city. Under the REAL banner, technology developers, learning deliverers and the citizens themselves have come together to be part of and to shape the 'learning city' community.

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[75] Further unpublished and extensive details of the methodology and results can be provided on request.

[76] www.didet.ac.uk.

[77] www.intoreal.com.

As part of these two case studies a number of examples of emergence were identified and explored. For the purpose of assessing the predictive and extrapolative powers of the multi-tiered typology in Chapter 7, subsection 7.3.2 a sample emergent from each case study is considered in detail below – (h) collective memory from DIDET and (j) social capital from REAL. For each emergent, an overview of the emergent from the original case study is first presented. This is then used to build a description of the emergent using the explanatory framework. The sample emergents are selected purely on an interesting case basis. Any of the other emergents could equally have been used.

B.1 (h) Collaborative working within DIDET

Narrative regarding the development of collaborative working within DIDET

Collaborative working was at the heart of the DIDET CLC. How it was achieved through the use of collaborative working technology (CWT) developed over the lifetime of the CLC, as the Event-state Network in Figure B-1 below and the accompanying narrative describe[78].

[78] It should be noted that certain practices described here, especially with respect to IPR and copyright have subsequently changed. These changes are outwith the scope of this research.

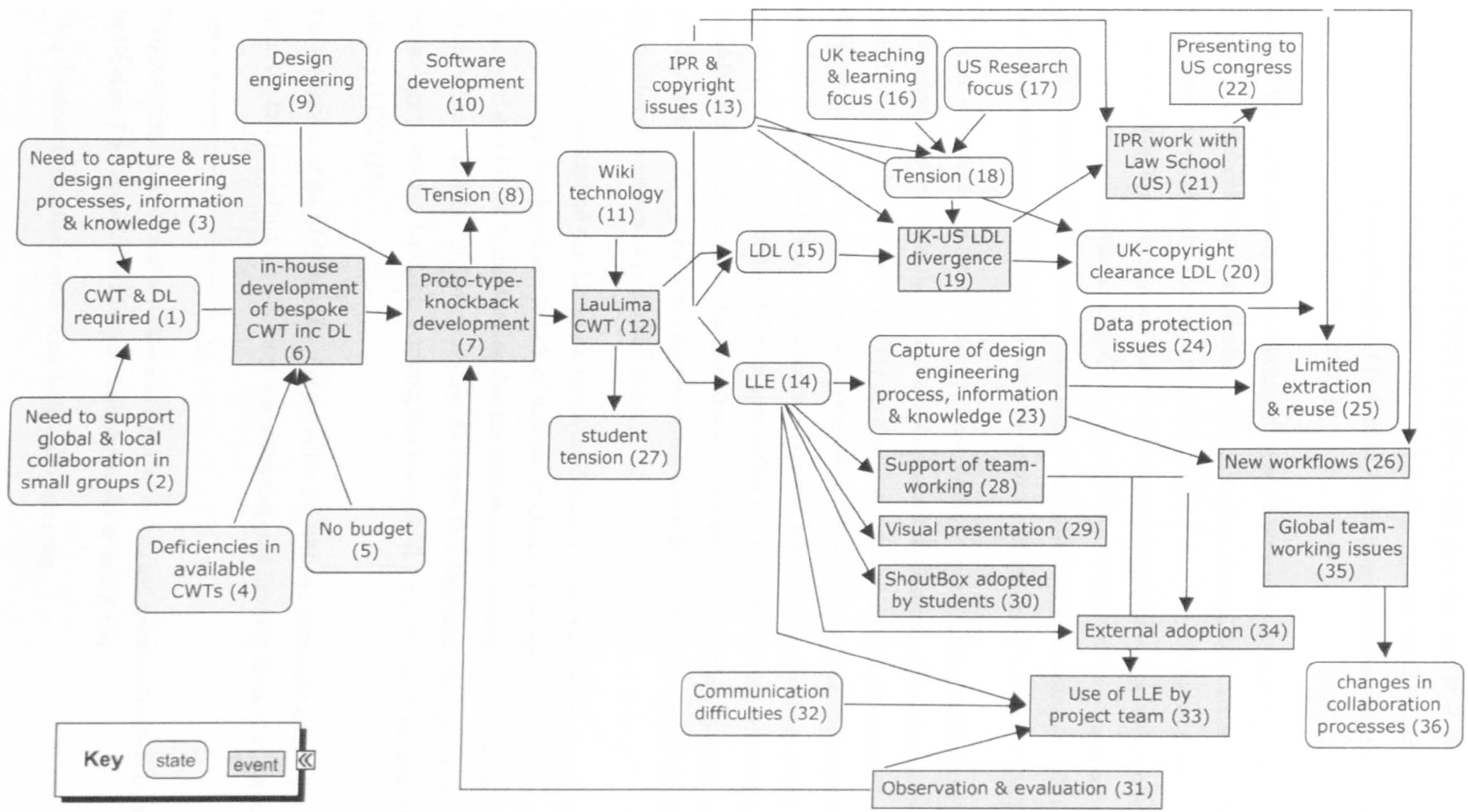

Figure B-1: Event-state network for the development of collaborative working within DIDET

As the Event-state Network of Figure B-1 above highlights, the need for CWT and a digital library (DL) (1) to underpin student global and local group activities (2), and coincidently capture the design process in action (3) were key drivers in the collaborative working approach which developed within DIDET.

While CWTs were already being successfully used within other design engineering spheres to enable virtual collaboration over both time and space, these CWTs' access control tended to be based on capabilities such as edit or delete rather than controlling access to working areas on a group basis. This meant that there was no guarantee that a group's work would remain private, making the existing CWTs unsuitable for the DIDET environment where group and individual based assessments were core to the planned learning (4). This combined with a lack of budget (5) led to in-house development of a bespoke CWT (6).

The core requirements were the ability to limit access by groups, the generation of appropriate audit trails and the inclusion of digital library features. Apart from these, specifications were quite loose and the development evolved in the light of experience and as different classes and tasks were added to the DIDET project. This "prototype-knockback development approach" (7) led to a degree of tension within the project team (8) as different members were accustomed to different approaches (9), (10). As existing wiki technology provided much of the required functionality (11), the decision was taken to adapt an existing public domain wiki[79] to introduce access control and other desired features. The resultant product became known as LauLima[80] (12).

It had been anticipated that LauLima would in addition contain the digital repository which was also being developed due to lack of suitable products. However, the problems with IPR and copyright (13) led to the decision that the collaborative working space should be distinct from the more 'official' digital repository. As Figure B-1 illustrates, this gave rise to two technology products – LauLima Learning Environment (LLE) (14) and LauLima Digital Library (LDL) (15).

The separation of the LLE and LDL did not solve the IPR and copyright issues. The problem lay in the fact that within the UK there was a teaching and learning focus (16) while the US

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[79] Tikiwiki (http://tikiwiki.org) was chosen as it met the criteria and was also already being used by the US team. Development was however carried out solely at the UK end.

[80] http://onlinelearning.dmem.strath.ac.uk/laulima/tiki-index.php.

partner had a research focus (17). In the latter, it was felt that strict application of copyright and IPR clearance would significantly inhibit research. This resulted in considerable tension (18) which led in a divergence of approaches within the two countries (19). Within the UK, strict copyright clearance procedures were introduced before data could be uploaded to the LDL (20). In the US on the other hand, the researchers formed a collaboration with their Law School (21) to investigate how the legal issues could be addressed without unduly restricting research, leading to a presentation to the US congress (22).

The divide between the more formal LDL and the informal LLE meant that in the LLE IPR and copyright restrictions could be less stringently applied, enabling the LLE to be used to record the ongoing development work (23) without too many overheads. While it had been the aim to use this resource for future teaching, data protection concerns (24) resulted in limited extraction and reuse (25). New workflows (26) were developed to capture meta-data before storage in the LDL.

The introduction of the LLE (14) led to some initial tension with students (27) - they felt they were being experimented on. This evaporated as the project progressed and they became used to using the LLE as a support tool for team-working (28). Indeed, they found it advantageous, adapting it to suit their needs in unanticipated ways. For example, the students began to use of the wiki as a presentation tool (29) – students combined visuals and textual explanation to develop on-line presentations of their projects. They then used the LLE in place of PowerPoint or other presentation tools during their 'end of project' presentations. Similarly, students started using the ShoutBox in the LLE for synchronous virtual communication (30); the ShoutBox - a 'left over' from the wiki adaption - became an extremely useful tool. Observations and scheduled evaluations (31) picked up these innovations and issues which had arisen, feeding them back to the prototype-knockback approach (7). This resulted in improvements to the LLE and LDL. It should be noted that the introduction of the LLE was not smooth as eLiteracy issues arose. This is omitted from Figure B-1 for clarity.

The observation of the success of the CWT (31) combined with the need for familiarity with the CWT and the problems with co-ordination of activities in a multidisciplinary team (32) led to the adoption by the project team of the CWT (33). A wider adoption (34) also occurred as students familiar with the wiki asked to use it for external projects and collaborations. For example, the formula student project used the CWT to design, build, develop, market and compete with a small, single seater racing car.

Despite the success of the bespoke LLE, there were still considerable problems in working collaboratively between the UK and US (35). The introduction of collaborative projects over video links supported by the LLE helped to overcome these issues (36).

Description of the emergence of collaborative working

The emergence relation

In the DIDET case study, both collaborative working and the technology used to support it were identified as products of a complex socio-technical system and hence emergent. This emergence is therefore diachronic as opposed to logical in nature. Collaboration arose from the need to achieve complex tasks and also, to a large extent, from the original purpose of the learning community. As Figure B-2 below illustrates, collaborative working can be considered a macro-level capability of the participants of DIDET. Thus, the emergence relation is the relation between collaboration and the individual participants within DIDIET and their objectives/tasks.

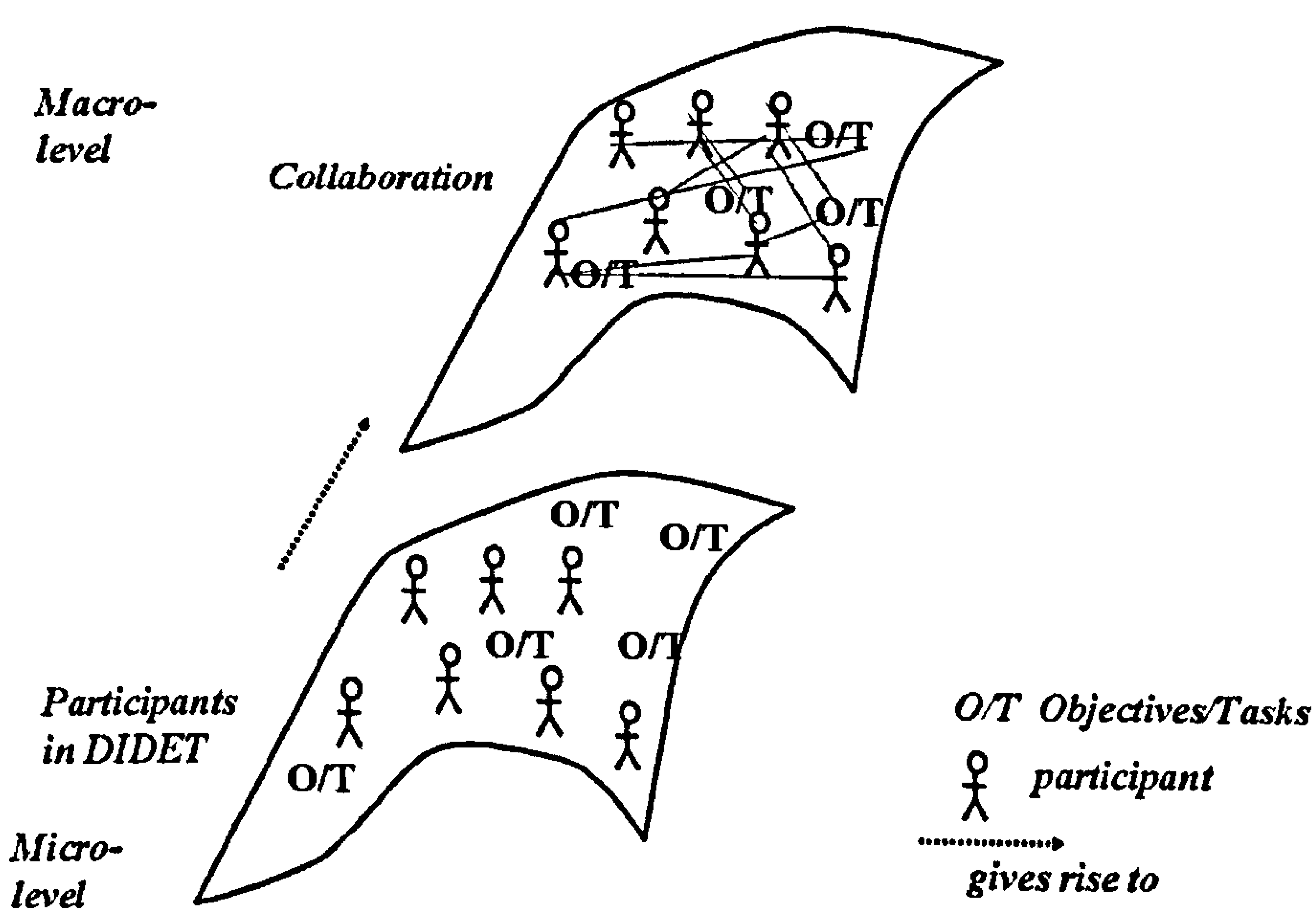

Figure B-2: Overview of the emergence system and emergence relations associated with collaborative working in DIDET

As people are the core micro-level components in collaborative working, it is to be expected epistemological factors such as observation and interpretation/theorising will play a causal role in the emergence associated with collaborative working. The emergence relation between DIDET participants and their collaboration is considered in further detail below.

Meta-relational properties of the emergence of collaborative working

Neither collaborative working nor the technology that developed to support it was a surprise to participants within DIDET, although the exact forms that these took were unexpected. Collaborative working was predictable based on understanding of collaboration although the complexities of tasks and number of outside influences meant that the exact form could not be predicted, making it predictable in principle only. Differing scope or resolution is unlikely to have led to significantly more precise predictions. The collaborative working practices that evolved are explainable in terms of the interaction of participants, key objectives or tasks that required to be fulfilled and outside constraints arising from funders or legal concerns. As these various influences were often interrelated, the explainability is in terms of a complex product. Again, differing scope or improved theorising is unlikely to reduce this complexity.

The meta-relational properties of the emergence of collaborative working within DIDET are summarised in Table B-1 below.

Meta-relational property		**Collaborative working**
Surprise		No
Predictability of emergent		In principle
	Scope	No
	Resolution	No
Reducibility of explanation		Complex product
	Scope	No
	Resolution	No

Table B-1: Analysis of meta-relational properties associated with the emergence of collaborative working within DIDET

Generators of collaborative working within DIDET

Component level constraints in the form of participant interaction were a core generator of collaboration. Macro-level constraints such as legal or funding requirements also were of significant causal influence in the emergence of collaboration. For example, the need to comply with IPR requirements dictated constraining processes and also the functionality of the collaborative working technology which was developed. Relational constraints were not a significant causal factor.

As the tasks undertaken within DIDET were to a large extent driven by the original objective of the learning community which was to explore the capture of tacit design knowledge through a collaborative partnership between a UK and a US higher education institution, design played a key role in construction. While there were attempts to deliberately generate or 'manufacture' collaboration through specific learning tasks etc, much of the collaboration developed through self-organisation within basic design constraints. For example, students adopted and adapted the basic tool set to enable collaborative presentation of results. As these collaborative processes evolved over time, prior emergence was built upon and leveraged to increase collaboration. The ongoing evolution and innovative use of the collaborative working technology is a good example of this. Further, the different experiences and skills of the participants and their abilities to identify and leverage new opportunities means that internal subjectivity within the emergence system was also a key causal factor.

Observation of potential opportunities to innovate and then implementing the innovations was also a key causal component. These innovations were not really related to theoretical understanding of collaboration etc, but rather much more tacit in nature and so reasoning was not really a significant generator, although there may have been an element. A wider scope or resolution may reveal different generators but it is unlikely that they would be of a different type. The generators of collaborative working within DIDET are summarised in Table B-2 below.

Generators		Collaborative working
Generators of macro-level properties	*Component constraints*	Yes
	Macro constraints	Yes
	Relational constraints	No
Construction	*Self-organisation*	Yes
	Manufacture	(Yes)
	Design	Yes
	Prior emergence	Yes

Generators		Collaborative working
	Subjectivity	Yes
Epistemo-logical generators	*Observation*	Yes
	Reasoning	(No)
Epistemo-logical influences	*Scope*	(Yes)
	Resolution	(Yes)

Table B-2: Analysis of generators of emergence of collaborative working within DIDET

Causal powers analysis

Collaboration was viewed as a powerful force in the success of the learning community and therefore collaboration may be considered to have a degree of macro-level causal powers. For example, the collaborations led to development of bespoke collaborative working technology. These apparent powers are reducible to a product of the capabilities and personalities of individuals and the set tasks. Adoption of a different scope or new theoretical understanding is, I would argue, unlikely to increase reducibility.

Collaborations could also be observed to affect the individual behaviour of DIDET participants. For example, a pull factor could be observed in that once participants engaged in effective collaboration they were more likely to seek further collaborations. Thus, collaborative working may be considered to have downward causation in that it acts as an attractor – focussing the ongoing behaviour of participants. Again, adoption of a different scope or new theoretical understanding is, I would argue, unlikely to affect the apparent downward causation.

The analysis of the causal powers associated with collaborative working within DIDET is summarised in Table B-3 below.

Causal power		Collaborative working
Macro-level		Product
	Scope	No
	Resolution	No

Downward causation		Attractor reducible
	Scope	No
	Resolution	No

Table B-3: Analysis of causal powers of collaborative working within DIDET

Conclusions regarding the emergence of collaborative working within DIDET

The emergence of collaborative working within DIDET is typical of the type of emergence found within complex socio-technical systems. The core micro-level components were the participants and their objectives/tasks. The emergent is predictable in principle only and reducible to a complex product of its lower level components. Like most emergents which develop within complex systems, the core generators were constraints – component and macro-level – with the development arising through self-organisation although some planning and manufacture was also in evidence. The apparent causal powers of the collaboration were again in line with those expected within complex systems.

B.2 (j) Social Capital within the REAL

Narrative regarding the development of social capital within REAL

Social capital developed by both learners and developers was a significant outcome of involvement with REAL. Its development by developers and practitioners rather than learners is considered. Building social capital for the various developers was not a primary focus of REAL; however, significant social capital arose. Figure B-3 below summarises the key factors in its development.

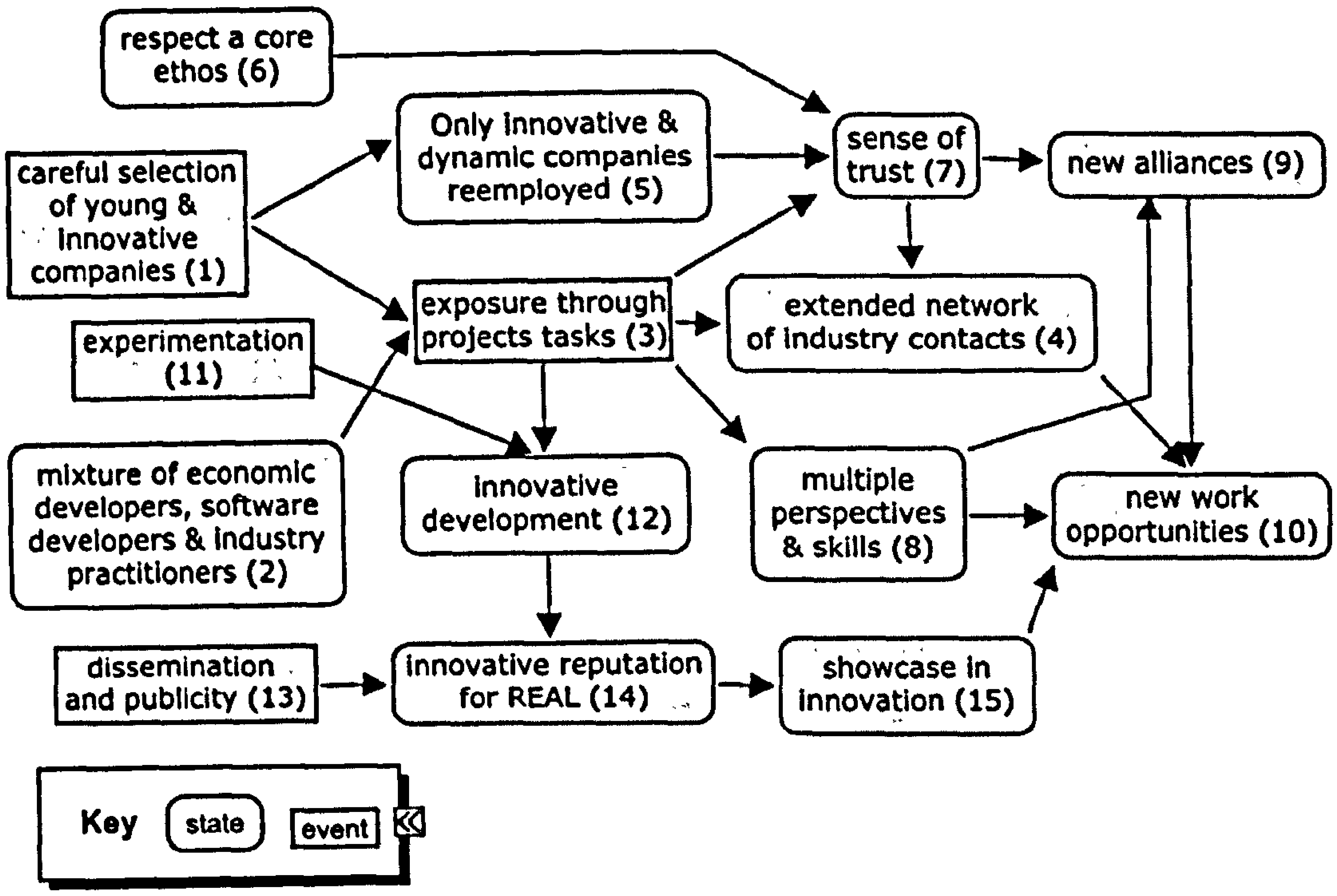

Figure B-3: Event-State network for the development and use of social capital by developers and practitioners within REAL

As Figure B-3 above illustrates, the careful selection of young and innovative companies (1) and the mix of economic developers, software developers and industry practitioners (2) were key starting points in the development of social capital by the developers and practitioners involved in REAL. Through working on specific projects or tasks (3), not only were networks of contact extended (4), but also the various developers and practitioners were exposed to each others' working practices and innovative outputs. This, combined with the fact that only innovative and dynamic companies were re-contracted (5) and mutual respect was a core ethos within REAL (6), led to the generation of a significant sense of trust within the developer and practitioner community (7). This meant that the various organisations and individuals involved were prepared to open up access to their business and social networks to their fellow developers and practitioners (4), significantly increasing the social capital of those involved.

The involvement in the development projects (3) led to exposure to complementary, often multi-disciplinary perspectives and skill sets (8). This combined with the trust which had formed (7) led to the development of alliances (9) between complementary organisations. Through these alliances and the extended network of contacts (4), the organisations involved were able to bid for new work opportunities - both within and outwith REAL (10) - which they would not have had the skill set or contacts to do alone.

The multiple perspectives and skill sets (8) also directly helped identify new opportunities (10). For example, the economic developers, on the lookout for ways to improve the business capacity of the city, were able to advise developers and industry practitioners of additional revenue streams which they would not otherwise have identified - another example of the increased ability of the organisations involved to leaver advantage through the structure of their relationships.

The social capital of the developers and practitioners was also significantly increased through the innovative nature of the project. From the outset, the local development agency provided an environment that actively encouraged experimentation (11). This, and the exposure to differing backgrounds through project participation (3), resulted in learning programmes which were highly innovative in terms of both delivery and supporting technologies (12). The success of the resulting learning programmes was widely disseminated and the publicity generated by the development agency (13), led to the development of a reputation of REAL as a highly successful and innovative learning community (14).

This reputation for success provided associated developers with not only a good CV - if you were involved in REAL you must be innovative - but REAL itself acted as a showcase for the developers' work (15). This showcase again greatly increased the social capital of the developers and practitioners as it acted as a conduit, connecting them to both prospective clients and other potential collaborators.

Thus, the environment cultivated by the local development agency and the young and innovative nature of the developers and practitioners involved, led to a significant increase in social capital and the ability to turn this into economic success.

Description of the emergence of social capital

The emergence relation

Social capital was introduced in Chapter 2, subsection 2.2(d) as an example of emergence. Like the concept of emergence itself, there are a variety of definitions of social capital, making pinning down the emergence relation difficult. At the crux of the many definitions is the idea that a social network has a capability – capital or 'wealth' that can be utilised for benefit – that individuals in isolation do not possess (Bourdieu 1983, Putnam 1995, Portes 1998). This networked capital is then a 'potential', similar to the functionality of a machine or the ability to smell of ammonia in that it is only realised in relation to some external requirement or process. For example, in REAL, the social capital in the network of practitioners enabled some practitioners to combine forces to win contracts which they could not have won on their own.

While social capital is often described as being possessed by an individual, this perspective does not really aid clarity when examining emergence. The social capital lies in the network of relationships that the individual can call upon and so while an individual may have access to a certain social capital, he or she does not strictly hold that capital. As Figure B-4 below illustrates, the social capital of a network lies in its interconnections, while the social capital of an individual lies in the relationship between the individual and his or her extended network of contacts. Social capital is realised in relation to some sort of objective or task.

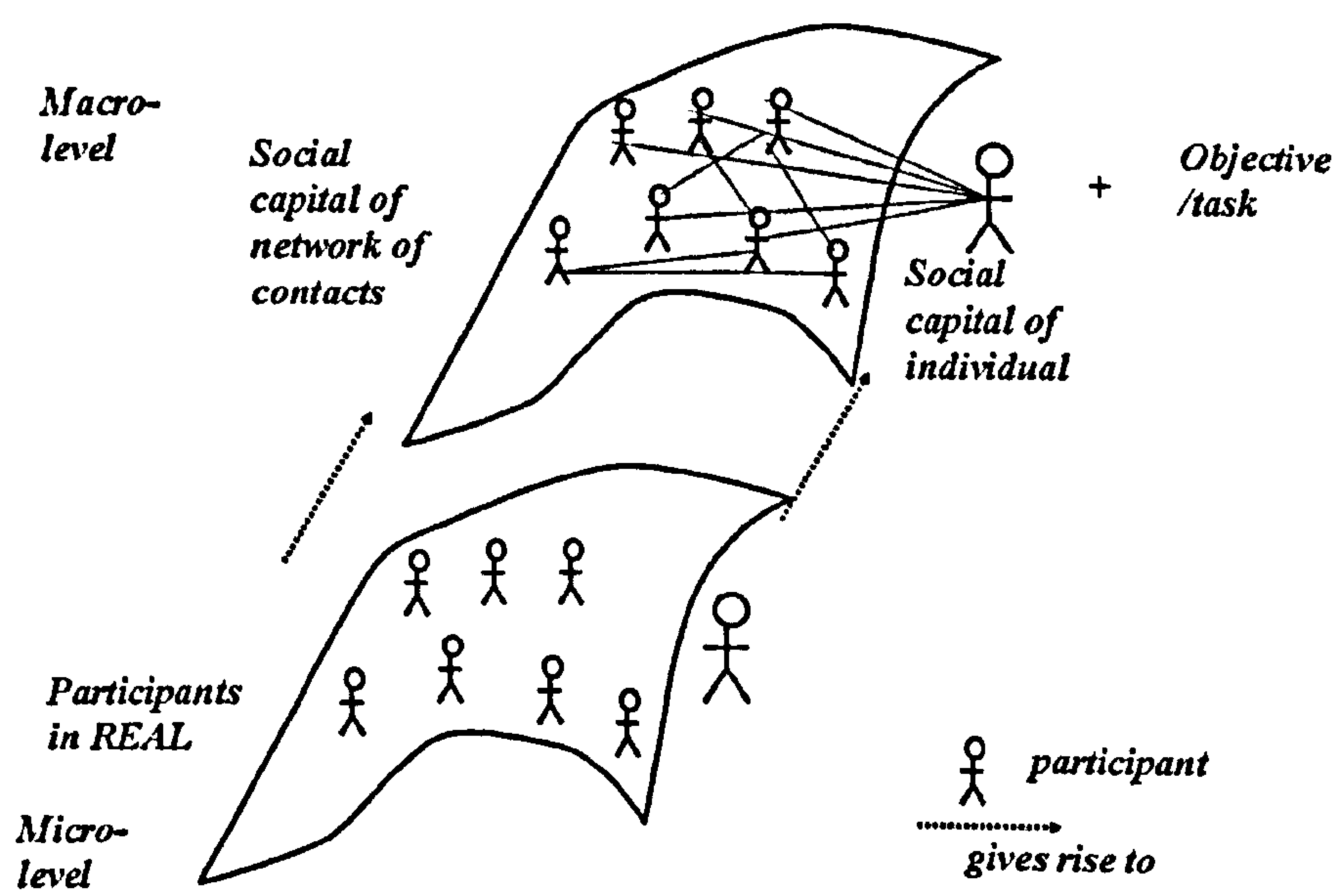

Figure B-4: Overview of the emergence system and emergence relations associated with social capital within REAL

As Figure B-4 above illustrates, human agency is core to social capital and hence epistemological influences are likely to play a causal role in how both social capital arises and how it is utilised. Further, as social capital is contained within the network of relationships, which will change over time, it is clearly dynamical in nature and the product of a complex socio-technical system.

The network social capital and the realisation of social capital by an individual are considered further below.

Meta-relational properties of the emergence of social capital

Within REAL, the emergence of social capital was not a surprise to practitioners as the Development Agency specifically emphasised the network of contacts and consequential advantages that involvement with REAL would bring. For the learners, who had not been introduced to the concept, the development of social capital was not exactly expected although they took considerable advantages of the contact with the professional practitioners, even after leaving the various projects. Whether these additional advantages engendered surprise or were simply just accepted is unclear. As the REAL case study clearly illustrates, the potential of social capital is increasingly being utilised within business and beyond. This theorising means that social capital is explainable in terms of individual properties and social connections. Thus, the existence of network social capital or an individual's ability to realise it is predictable, but the exact form and extent depends of the non-linear dynamics within the social network and hence is predictable in principle only. Given the complex nature of social interactions, it is highly unlikely that better theory or a wider scope will increase predictability. As social capital is essentially the product of social networks, its explanation is best achieved through a complex product of individual aims and objectives and contacts. Again, it is highly unlikely that better theory or a wider scope will increase its reducibility. The meta-relational properties of the emergence of social capital within REAL are summarised in Table B-4 below.

Meta-relational property	**Social capital of practitioner network**	**Realisation of social capital by an individual**
Surprise	No	No
Predictability of emergent	In principle	In principle
Scope	No	No
Resolution	No	No
Reducibility of explanation	Complex product	Complex product
Scope	No	No
Resolution	No	No

Table B-4: Analysis of meta-relational properties associated with the emergence of social capital within REAL

Generators of social capital within REAL

The relationship between individual practitioners within REAL was the main generator of social capital. However, as these relationships developed because of REAL itself or its individual projects, macro-level constraints should also be considered a key causal factor. The networked social capital is not itself directly accounted for in a relational constraint between a practitioner or learner and an external object, although any particular instance of its utilisation by a practitioner is. For example, while the capability to leverage different income streams gradually developed through the REAL professional contact network which grew up around the practitioners, it was only when a specific external contractual opportunity arose and highlighted by the Development Agency that the practitioners realised that this particular social capital could be utilised. The philosophy behind REAL was that of "organic development", where the Development Agency put key structures and opportunities in place, but then left the practitioners to interact and develop innovative learning initiatives, and as a result new relationships, bounded by broad guidelines. Thus, design for self-organisation was the key construction method. As emerging ideas and trends were continually built upon, prior emergence played a key role. Further, as participants were actively encouraged to be diverse and to scan what was happening to look for new opportunities and insights, subjectivity was also a key feature both in the development and realisation of social capital. As participant observation and also potentially insight were key, observation and reasoning was a key epistemological causal contribution to the realisation of social capital. The networked capital would exist whether or not it was observed or reasoned about. A wider scope or resolution may reveal different generators but it is unlikely that they would be of a different type. The generators of social capital within REAL are summarised in Table B-5.

Generators		**Social capital of practitioner network**	**Realisation of social capital by an individual**
Generators of macro-level properties	*Component constraints*	Yes	Yes
	Macro constraints	Yes	Yes
	Relational constraints	No	Yes
Construc -tion	*Self-organisation*	Yes	Yes
	Manufacture	No	No

Generators		Social capital of practitioner network	Realisation of social capital by an individual
	Design	Yes	Yes
	Prior emergence	Yes	Yes
	Subjectivity	Yes	Yes
Epistemo-logical generators	*Observation*	No	Yes
	Reasoning	No	(Yes)
Epistemo-logical influences	*Scope*	(Yes)	(Yes)
	Resolution	(Yes)	(Yes)

Table B-5: Analysis of generators of emergence of social capital within REAL

Causal powers analysis

The networked and multi-levelled nature of social interaction makes analysis of the causal powers of social capital difficult. As social capital is an explanatory tool within the social sciences it might reasonably be expected to have a degree of causal power although this may of course be reducible. For example, within REAL, social capital was used to 'explain' the ability of various practitioners to expand their client base. These new abilities are a product of the links between various members of the social network. The same may be said for the realisation of social capital relating to an individual. However, in this case the concept of individual levels is less clear as the emergent lies in the relationship between a network and an individual and thus the whole concept of macro-level causal power is questionable. Adoption of a different scope or new theoretical understanding is, I would argue, unlikely to increase reducibility. The social capital within a network does appear to influence the individual network members. Once a certain-level of social capital occurs, positive feedback appears to influence further accrual from potentially different sources. Thus, an element of attractor dynamics may occur. There may also be a claim that the social capital within the network also constrains the activities of individual members as they want to maintain access to the capital. This latter behaviour is a choice of the network participants – the component parts - and so I would suggest does not really qualify as constraining downward causation. However, where social capital is actually realised agreements or commitments may actually constrain individual behaviour. Again, adoption of a different scope or theoretical understanding is, I would argue, unlikely to affect the apparent downward causation. The analysis of the causal powers associated with social capital is summarised in Table B-6.

Causal power	**Social capital of practitioner network**	**Realisation of social capital by an individual**
Macro-level	Product	(Product)
Scope	No	No
Resolution	No	No
Downward causation	Attractor reducible	Constraining
Scope	No	No
Resolution	No	No

Table B-6: Analysis of causal powers of social capital within REAL

Conclusions regarding the emergence associated with social capital in REAL

The emergence of social capital within REAL is again typical of the type of emergence found within socio-technical systems. It differs from the collaboration example (h) in that it is often viewed as belonging to an individual. Thus it is useful to distinguish network social capital and its realisation by an individual. In the former case the emergence relationship is between individual participants and the global properties of their social network and in the latter case it is between these participants and properties, the individual participant and the task at hand. In this latter view, social capital exists in the relationship between an individual and their network of contacts and so in this case relational constraints play a key causal role. Both the social capital of the network and that realised by an individual also have component and macro-level constraints as causal factors, with self-organisation playing a significant role – all typical generators of emergents which develop within complex system. Again, there was an element of design involved too. The apparent causal powers of the collaboration were again in line with those expected within complex systems. Social capital also has similarities to the case of functionality of a machine in that it is a potential, which is only achieved in relation to a particular task or objective.

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