Using systems theory to do philosophy:

One approach, and some suggested terminology.

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Abstract

This thesis employs perspectives inspired by General Systems Theory to address issues in philosophy, including moral philosophy and philosophy of mind. I present an overview of a range of ideas from the study of physical systems that may be used to provide a firm physicalist foundation to explorations of some common questions in philosophy. I divide these topics into three categories: the Physical Category, the Relevance Category and the Signal Elements Category.

I interpret concepts from General Systems Theory, including information and entropy, in a way that I believe facilitates their incorporation into philosophical discussion. I also explain various points arising from General Systems Theory, such as order and disorder, stability, complexity, and self-organisation, and show how ideas from these areas can be applied to certain philosophical problems.

I explain relevance in terms of stability, in order to link these scientific perspectives to questions in moral philosophy. I suggest a possible physical foundation for a theory of morality, which takes the form of a variety of Utilitarianism, intended to balance the competing needs of open systems to manage entropy. Such a theory of morality must be capable of dealing with limitations arising from the physicality of information; I propose game theory as a solution to this problem.

This thesis also covers issues connected to the above points regarding the nature of consciousness and communication. In particular, I examine the role of linguistic associations in consciousness; and some related features of language and other non-linear representational schemes.

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“Unless the cold pierces through our bones once, how can we have the apricot blossoms perfuming the whole world?”

Dōgen Zenji, *Eihei Koroku* §19

1. Introduction

In "Energy systems and the unification of science", the systems theorist Howard T. Odum wrote, "There has been for many years a crisis in Philosophy. Philosophy once claimed to be the most general of intellectual fields but lost that intellectual leadership of pure ideas, perhaps because its practitioners did not become quantitative or test their concepts against quantitative evaluations of the real world. General systems theories are a way of reuniting the fields that seek to generalize knowledge." (1995:368). In this thesis, I propose to discuss some ideas taken from General Systems Theory in a way that makes them useful to certain questions in philosophy of consciousness, and morality. I hope thereby to help facilitate the rapprochement between science and philosophy that has been evident in recent years in areas such as neuroscience and physics. The main ideas that I will take from systems theory are the nature of complexity, stability and self-organisation, and the implications of the universe being a closed system.

I will attempt to construct an explanatory scheme that starts from some of the most basic physical features of our universe and finishes with an approach to some abstract philosophical questions. Given the necessarily short length of this thesis, I will unfortunately be forced to sacrifice some detail in the description of the various elements of this scheme. However, these topics, which range from gravity to game theory, each have many hundreds of books devoted to them. I hope that brief explanations of each topic will therefore be sufficient as "signposts", as I describe the overall shape of my approach to using systems theory to do philosophy. The intention is to point out some of the most useful topics in these subjects for doing philosophy.

1.1 What is General Systems Theory?

General Systems Theory, as the name implies, is the study of the general features of systems. It is one way of studying how things interrelate. It looks at order and disorder, patterns, complexity, and change over time.

Speaking generally, a system can be just about anything we can identify, analyse and discuss. A system is "any definable set of components." (Maturana and Varela 1980:138). The Internet is a system of computers connected together by cables, switches, and so forth; and all these elements can also be viewed independently as systems themselves. A glass bottle is a system made up of silicon dioxide molecules connected to form a certain shape; and a molecule can also be considered as a system. General Systems Theory (hereafter "systems theory") provides mathematical and other conceptual frameworks for describing systems and their interaction. One common topic in systems theory is the way in which systems make use of energy to maintain themselves.

"A system is a set of interrelated elements, each of which is related directly or indirectly to every other element, and no subset of which is unrelated to any other subset." (Ackoff and Emery 1972:18). A collection of elements will be identified as a system in a particular context[1], by specific observers. Language and behaviour both influence decisions on what to identify as a system.

System theory has potential as a unifying scheme that is useful to those of us in other areas of knowledge because it provides ways to talk about the general features of how things interrelate. Systems theory has been applied to topics ranging from

[1] The exception to the rule that systems are defined in a context is the largest possible system, which we call the universe. Although some physicists postulate the existence of a "multiverse", containing many different universes (Smolin 1997, Rees 2001), I will not address such theories in this thesis, since they remain highly speculative.

cosmology to ecology to economics. The reason for this broad applicability, in my opinion, is that systems theory can quantify the fundamental physical features of our universe that we describe using terms such as energy, entropy, probability, and topology. This solid foundation in the physical gives systems theory great practical utility across many fields of study.

1.2 A brief history of General Systems Theory

Systems theory began as an attempt to better understand organic systems by applying ideas from physics and engineering, in the late 1920s. Over time, it was strongly influenced by the engineering discipline of control systems, as well as developments in thermodynamics and information theory, as well as topology. In recent years, systems theory has been much concerned with the nature of complex dynamical systems, including chaos theory and catastrophe theory. Systems theory has also been applied to economics, politics, sociology, psychology, management theory, and computing.

The idea of open and closed systems was introduced in 1925 by the mathematician Alfred Lotka. However, it is the biologist Ludwig von Bertalanffy who is considered to be the "founder" of systems theory as a discipline (Kramer 1977:5). Other important names include inventor of the idea of homeostasis, physiologist Walter Cannon; cybernetics pioneer Norbert Wiener; Claude Shannon, who was one of the founders of information theory; H. T. Odum and Fritjof Capra in the field of ecology; and complexity theorist John H. Holland. More loosely associated writers include Noam Chomsky, who pioneered the idea of generative grammar; and self-organisation theorists James Lovelock, Stuart Kaufmann, and John von Neumann. Alan Turing's writings on computability and morphogenesis have also been influential in systems theory. Marshall McLuhan's *Understanding Media: The Extensions of Man* is also related to systems theory, emphasising the consequences of the physical aspects of the medium by which communication takes place.

Systems theory is not a theory in the traditional sense of the word, as in "the theory of relativity". Rather, it is a school of thought united by common concerns and tools of analysis, as are philosophy, sociology or psychology, for example. For that reason it is sometimes called "systems thinking" or "the systems approach". The diverse writings on systems theory are united by the technique of using of concepts from thermodynamics, mathematics, and other "hard sciences" to provide rigour in other areas of investigation. In this thesis, I will not be offering any formal schemes such as ways of modelling dynamic processes, one common strategy of systems theorists. Rather, I will simply be trying to show connections between different ideas that fall within the rubric of systems theory, in order to draw attention their potential application to philosophical questions.

1.3 A general overview of the structure of the thesis

This thesis suggests a scheme involving three broad ways of categorising scientific and philosophical topics. The three categories are the Physical Category, the Relevance Category, and the Signal Elements Category. These three categories are not separate, but should be viewed as nested sets, with the Physical Category being the most comprehensive. Furthermore, the assignation of one topic or another to a particular category is to some extent a matter of personal preference. For example, information has a physical basis, but is also connected to topics that fall more naturally into the Relevance Category, since information can be relevant or irrelevant. The three categories will each be discussed in the next three chapters of this thesis.

This thesis, these three categories as concepts, and indeed systems theory itself, are classified in the Signal Elements Category. This leads to a certain degree of self-reference. I believe that it is a mistake to view this as problematic. Indeed, we should expect the issue of self-reference to arise many times in the course of this thesis, which is partly about the observation of observation. On the contrary, problems would be more likely to arise if we viewed this conceptual scheme as a "special case", somehow qualitatively different from the other academic topics that it discusses.

I will proceed to give a brief explanation of how these three categories are used. I will skip over various technical points rather quickly; the reader should proceed to the main text for further explanation.

I should first make clear, although it may seem rather obvious, that this thesis is a linguistic construction intended to provide a useful way of addressing issues in philosophy and science. It is a form of communication in the traditional Western academic mode. However, this thesis includes discussion on the features of our subjective consciousness besides the linguistic. I wish to emphasise to the reader that the explanations that constitute this thesis are intended to be practical as well as conceptual, and to be applicable to understanding aspects of consciousness other than language and logic, although the thesis itself consists of nothing but language and logic.

The problem of trying to discuss, through communication, the gap between communication and other aspects of consciousness is another example of self-reference. The topic of the apparent inability of communication to fully capture subjective experience will be one of the philosophical issues addressed in the course of this thesis.

1.3.1 The Physical Category

The purpose of the Physical Category is to explore the consequences of the idea that the universe is a closed system; particularly the consequences for we observers within that closed system. Besides the consequences of inhabiting a closed system, the other major topic taken from systems theory in the discussion of the Physical Category is the idea of complexity.

My explanation of the Physical Category is intended to be compatible with current cosmology, relativity theory, and quantum physics. It should also be compatible with theories of the "informational universe" as proposed by physicist John Wheeler and others. This compatibility is intended to provide a solid foundation for the later philosophical discussion.

Two characteristics of closed systems that are important in the Physical Category are background independence (the absence of points of reference that are absolutely fixed for all observers), and the existence of limits to what an observer can know about the closed system that the observer inhabits.

Perhaps the central idea of the Physical Category is the concept of probability. It is this emphasis on probability which allows the Physical Category to be compatible with quantum physics. I do not insist on what is known in quantum physics as "realism", instead viewing reality as statistical, and my explanatory scheme therefore can cope with physicist John Bell's discovery of reasons, stemming from what are known as "Bell's Inequalities", for thinking that quantum physics simply cannot be interpreted both realistically and as involving local causal determinism (Brooks 2007). Any philosophical scheme that hopes to incorporate the consequences of the universe being a closed system must be able to deal with problems of quantum uncertainty, which means incorporating probability as fundamental somewhere.

The description of the Physical Category starts with a probabilistic formulation of the concept of entropy, which is the general statistical tendency towards disorder, in systems for which probability is not significantly affected by gravity. The idea of entropy runs right through this thesis, touching on my discussion of stability in terms of probabilistic attractors; the nature of self-organisation; and the basis of morality. Entropy provides one of the main ways by which my physical explanations connect with my discussion of problems in philosophy.

After entropy, my discussion of the Physical Category proceeds to the role of gravity, without the organising influence of which there could not be open systems (such as ourselves) within our closed-system universe. (An open system is one which takes in energy from its environment.) Although the concept of gravity is an important foundational one for the Physical Category, it is not directly related to issues in systems theory, and so is treated rather briefly.

There follows a discussion of the concept of time, focussing particularly on the connection between observation in a closed system, and the arrow of time. Time obviously has an important correlation with the idea of probability, which is always assessed in a temporal context, being a way of specifying change. However, time, like gravity, is part of the background of the Physical Category, and is not discussed beyond the first chapter.

The next section covers information, which I define as change measured by an observer at a particular location. Information can be relevant or irrelevant; but the basis of relevance cannot be fully explained until we reach the description of the Relevance Category. Information is a natural intersection of the Physical Category and Relevance Category, since while I agree with the systems-theory slogan "information is physical", assessment of relevance of information depends on the situation of the observer. This topic therefore looks ahead to some extent, to topics that will arise again in other contexts. The discussion of information mainly deals with the consequences of the closed-system universe: background independence, and horizons to knowledge for a given observer.

The discussion of the Physical Category ends with a look at the origins of complexity. This section focuses on order and disorder, feedback and thresholds, nonlinearity, and the idea of stability.

The discussion of stability begins with the concept of Self-Organised Criticalities (SOCs). SOCs arise in complex dynamic systems that contain many elements that bear some kind of threshold between different states, or in other words, elements that can move from one probabilistic attractor to another in what is known as "phase space". These elements are arranged in a way that allows weak local feedback. The SOC system as a whole will tend to move back into a stable state after being disturbed: it lies within an attractor that allows metastability (stability where entropic probabilities have not yet been fully pursued, thanks to the existence of an open system at some point in the process by which the system was formed). An example is a mountainside prone to avalanches: having the right number of the right size rocks in the right proximity, etc. The threshold is provided by the coefficient of friction of individual rocks, while feedback is provided by physical contact. This is the simplest form of self-organisation.

The next section covers more complex self-organisation, when different interacting subsystems are considered as elements of a larger system, which can achieve dynamic equilibriums. The interaction of the elements of this system allows it to remain stable, in a way that is more dynamic and robust than simple SOC systems. This provides the final foundation necessary to proceed to the Relevance Category.

1.3.2 The Relevance Category

The central idea of the Relevance Category is stability, and particularly stability that arises from self-organisation. Most of the discussion in this chapter deals with the consequences of self-organisation. Self-organising systems are open systems, obtaining their energy ultimately from the effects of gravity, within the closed system of the universe as a whole. In this chapter, I give an outline of a way in which relevance as I have defined it, including game theory, can be used to provide a basis for a utilitarian system of morality which is compatible with a physical, closed-system universe. The Relevance Category begins with an examination of the connection between stability and relevance.

The next section in the Relevance Category covers what I call entropy management, although this idea could equally be named "systems management", "stability management", or "probability management". This discussion explains why entropy management is necessarily undertaken by all homeostatic systems, and the connection between entropy management and relevance.

Complex dynamic systems allow for the possibility of game theory, the next topic in my description of the Relevance Category. Game theory results from a self-organising system recognising relevant information regarding other self-organising systems, in the course of competition for resources necessary for survival of the system. This permits the system to develop behaviour that improves its chances of survival. Game theory provides a way to quantify conflict and co-operation between processes that have different standards of relevance: the most important being immediate relevance to physical survival.

I next discuss Dawkins' idea of memes, which are subject to evolutionary pressures. I define memes as probabilistic attractors for behaviour, rather than as abstract concepts linguistically expressed. One example of a meme is a word: but a specific word, such as “word”, is not a meme but an element within a wider behavioural system. Here again we run into issues of self-reference. The discussion of memes also continues in the next chapter.

The final part of the Relevance Category chapter is an examination of some of the issues surrounding consciousness, which certainly has implications for the nature of observation as well as morality.

1.3.3 The Signal Elements Category

The Signal Elements Category is composed of particular types of memes (memes being behavioural attractors identified within an interconnected context) which are used for communication and other forms of expression by self-organising systems. I use the term “signal elements” to emphasise the point that any such form of communication, such as an English sentence, must exist as part of a broader system, from which it gains its meaning in a context of differentiation. The Signal Elements Category covers areas such as language, mathematics, logic, art, and music. I will begin discussion of this area with a brief explanation of the connections between memes, associations and grammar.

The Signal Elements Category discussion also covers some of the limitations of language, with regard to dealing with complexity, the physical nature of information, and consciousness. For this third point, I take my cue from Wittgenstein’s *Philosophical Investigations* (1953).

The thesis concludes with some brief notes on possible applications to Heidegger’s *Being and Time* (1963) and the Chinese *Chan* 禪 Buddhist literary tradition.

1.4 Geometry and topology

Although I do not have the space to provide details in this thesis, the mathematical background of all of these ideas should be considered to be geometric, and in particular, topological. As mentioned at the beginning of this thesis, Howard T. Odum sees systems theory as having an important role to play in unifying certain areas of knowledge. I certainly agree with this proposition, and it is the focus of this thesis. However, I believe geometry is the most basic technique by which these fields can be unified. This is because geometry explains the ways in which elements of systems can be connected or separated, and thereby the ways in which different systems can resemble each other, and is capable of maintaining this rigorous analysis for multi-dimensional systems that are extremely difficult to visualise. Geometrical mathematics can also provide a way of comparing the different classificatory schemes that systems theorists come up with. It is an important tool in constructing formal descriptions of nonlinear phenomena that resist such analysis due to their extreme complexity.

If one abandons “realism” in quantum physics, observed reality is considered to be statistical, rather than absolute. Geometry, as a way of specifying possibilities, is able to cope with a statistical view of reality. It has therefore seen much use in quantum physics, and in particular, the attempt to reconcile quantum physics with relativity theory known as quantum gravity theory. One example is John Wheeler’s theory of geometrodynamics (Wheeler 1963), extended by physicist Christopher Isham into an attempt to do quantum gravity theory using topos theory, which grew out of topology (Matthews 2007). Geometry is important for loop quantum gravity and string theory, which make use of topos theory and knot theory (which is another aspect of topology) (Smolin 2000).

By incorporating probability, logic in topos theory is capable of dealing with horizons which limit the information that can be received by an observer at a given location (Smolin 2000:31). This is one topic found in my explanation of the Physical Category. Probability is also very significant in the discussion of order and disorder, feedback and nonlinearity, and metastability.

Geometry is also important to the concept of multi-dimensional landscapes, which comes up many times in the course of this thesis, and which is a signature technique of systems theory. Examples include phase space (a geometric view of the possible states of a system), attractors (areas within phase space which direct probable change in a system, and which can allow a system to achieve stability), fitness landscapes (a geometric view of the game-theoretic competition of systems for survival), design space (a way of interrelating different functional strategies geometrically) and finally my explanation of the structured association of specific instances of behaviour involving memes used for communication (such as language and art).

Although we visualise such abstract landscapes as two-dimensional surfaces with hills and valleys, in fact they have many more dimensions, often including a temporal dimension (the first three examples given have a temporal dimension, and the latter two do not). Topology can be used to describe possible movements across these multi-dimensional landscapes.

1.4.1 Topology and topos theory

Topology is one way of specifying what is possible and what is not for particular systems. As such, it has found practical use in areas as diverse as image compression and fluid dynamics. Topology is considered to have begun with Leonhard Euler's 1736 answer to a mathematics problem known as "the Seven Bridges of Königsberg". Two islands in a river are connected to the river banks and each other by seven bridges. Euler showed that it is not possible to walk a route across all seven of the Königsberg bridges that crosses each bridge only once.

The exact shape of the islands and river banks is not relevant to this topological problem, although it would be relevant to determining the lengths of candidate paths. Topology deals with abstract maps that allow judgements of what is permitted by the connections or separations of elements in a system. For example, in topology a cube resembles a sphere, but a torus does not. If one imagines inflating the cube with air, it would become spherical; but inflating the torus with air would never result in a sphere. The cube is *homeomorphic* with the sphere: mathematical functions performed "on the surfaces" of the two shapes will be equivalent. The torus is not homeomorphic with the sphere. As it is inflated, the hole in the middle of the torus will become thinner, forming an infinitely thin singularity if the operation is performed using mathematics, rather than a rubber inner-tube. One could conceivably "cut the ends" of the singularity, and "patch them over", creating a sphere. The mathematical process analogous to "filling shapes with air" is known as Ricci flow.

Ordinary physical shapes are two-dimensional, in that we consider them in terms of surfaces. However, other systems can be made up of more than two dimensions, and topology can be applied to these systems also. One famous question in topology, known as the Poincaré conjecture, asked whether simple shapes in three dimensions were homeomorphic with a three-dimensional sphere, in the same way as for two dimensions. This question, which mathematicians have been working on for many decades, and for which a prize of one million dollars has been offered by the Clay Mathematics Institute, was recently answered in the affirmative (Mackenzie 2006).

Other questions involving possibility in topology include determining the minimum numbers of colours required to create maps showing the boundaries of distinct regions; and determining whether knotted loops can be untangled to form a simple circle, without cutting. A branch of topology known as Morse functions describes topological effects such as rising water turning two hills separated by a valley into separate islands.

Topos theory is another way of determining what is possible for certain systems, but which focuses on sets or categories rather than shapes. It can therefore be used to unify topology with logic. Topos theory evolved out of set theory and forms part of category theory – toposes are different ways of specifying categories of sets. Mathematicians in the 1930s came to realise that many mathematical concepts could be described by using maps that preserved their basic structure (called *morphisms*), and that this enabled these concepts to be used independently from classical set theory. "Thus gradually arose the view that the essence of a mathematical structure is to be sought not in its internal constitution as a set-theoretical entity, but rather in the form of its relationship with other structures through the network of morphisms" (Bell 1988:236). This enabled topos theory to be taken up in France by the structuralist Bourbaki school. John Bell goes on to say that "the category-theoretic meaning of a mathematical concept is determined only in relation to a 'category of discourse' which can itself *vary*. Thus the effect of casting a mathematical concept in category-theoretic terms is to confer a degree of *ambiguity of reference* on the concept" (Ibid:237). This gives mathematical concepts a kind of background independence, and Bell suggests that "the topos-theoretic interpretation of mathematical concepts bears the same relation to classical set theory as relativity theory does to classical physics" (Ibid:242). Indeed, as mentioned above, physicists such as Fotini Markopoulou and Chris Isham use topos theory in their attempts to unify quantum physics with relativity theory (the latter having background independence).

Although the mathematical details of geometry, topology and topos theory are not directly relevant to this thesis, I do wish to emphasise in this introduction that many of the ideas here have applicability to geometrical mathematics. I believe that this contributes to the solid physical foundation that is one of the advantages of using systems theory as a way of approaching philosophy. I should anticipate that a more thorough fleshing-out of the conceptual scheme that I present in this thesis would have recourse to these aspects of mathematics and logic.

For example, besides the use of topology in determining possibilities of movement across multi-dimensional abstract landscapes such as phase space, I consider that topology has an important role to play in explaining the functional mapping we use to create abstract conceptual schemes such as the rules of a sport, or a satire, parody or caricature, or a computer game like a flight simulator. Guerino Mazzola undertakes an exhaustive study of the geometric logic of music theory and performance in his book "The Topos of Music" (2000). Topology can be used for transformations of one system into another with different dimensions, like Fourier transformations that allow the sounds of an orchestra to be represented in the groove of a record, or the "holographic theory" in cosmology, which postulates that it is not necessarily possible for an observer in a closed-system universe to be sure of how many dimensions that universe possesses (this is discussed in the next chapter). Indeed, the most important feature of geometric mathematics and logic, for my purposes, is that they are capable of dealing with the implications of the universe as a closed system, such as background independence and horizons to the propagation of information.

1.4.2 Topology and information flow

Topology, as a way of exploring the implications of connectedness and separation of the elements that make up a system, provides a means for modelling the possibilities of information flow. (Information being defined in this thesis in terms of change.) Since it has become possible in recent years to use topology to do logic, one may also say that logic can be seen as a way of modelling information flow.

In this thesis, I adopt the physicalist position that to say something exists implies that there is some physical foundation to that existence. For example, although I do not maintain that brain processes (such as neural activity) and consciousness (such as awareness of a speeding car) can usefully be described as *identical*, still I believe that consciousness of the speeding car is founded upon physical changes occurring within the nervous system. To put it another way, the existence, in good working order, of the physical system that we call the nervous system (and potentially other physical systems, such as muscle fibres and other aspects of the environment with which the system is connected) is sufficient for consciousness to arise; but that being said, the above-mentioned systems are things that we are aware of, on the basis of information transfer. The attempt to observe the faculty of observation runs into difficulties of self-reference.

I hold that information is physical: information, according to my definition, involves change propagating through physical systems and being measured by an observer at a particular location. (I will provide details on this assertion below. Here I will note that "observer" does not necessarily mean "conscious observer".) Propagation of change implies some form of connectedness. If two elements of a system or systems are not connected in any way, then it is obviously the case that they cannot influence each other. If the elements are connected, then it is possible (but not necessary) that change in one can lead to change in the other.

This is not to rule out the possibility of action at a distance, although I do not hold much hope for experimental proof of that phenomenon. Regardless, if change in one system can lead to change in another, then there must be some way in which the two are connected. Otherwise it makes little sense to talk of causation. This is an important principle for physicalism.

The question of whether a tangled, interlaced loop of string can be transformed into a simple circular loop without cutting is a typical question in topology. One can characterise this question in terms of the physical possibilities of change to propagate through the system. But topology is not restricted to describing simple physical shapes. It can be used to analyse similarities in the possibilities of information flow among systems that are diverse in their physical shape, or in the number of dimensions that they inhabit. Topology can be used to abstract the possible courses of information flow without taking account of physical aspects of the system that go beyond connectedness and separation. This allows the possibility of simulation, or modelling, which is vitally important in game theory.

Topology is accordingly also relevant in determinations of the extent to which two systems are independent of each other. If neither of two systems can influence the other, they can be considered independent. For example, solar systems existing in regions that have been out of contact since the Big Bang would be completely independent. Two anthills on either side of the Earth should be independent for all practical purposes, although the two physical systems (made up of ants and dirt) would experience a tiny amount of mutual gravitational attraction.

One could also perhaps make a case that the topological properties of connection and separation provide a physical basis for instantiating binary integers (bits) of information: the answer to a "yes or no" question, for example. This is an important concept in information theory.

1.4.3 The meaning of "statistical"

This thesis often uses the words "statistical" and "statistical mechanics". These terms should be taken as referring to the presence of probability in any kind of change. Statistical mechanics derives from the physicality of information (propagation of information requires change).

Topology describes certain aspects of the *possibility* of change, while probability refers to the likelihood of certain specific changes occurring. Probability is the characterisation of the combined effects of many physical changes influencing each other, according to their topology, including physical factors like gravity and other forces.[2]

It is possible for systems to get into states where the combined physical probabilities of the system lead to stability. Rather like a leaf on a stream being pulled into a vortex, a certain range of similar states of the system may tend to persist. This may lead to disorder, such as the dispersal of a cloud of gas. Indeed, disorder is (generally speaking) more probable within the closed-system universe than order, according to the Second Law of Thermodynamics: if one threw a hundred dice, one would be surprised if they all came up with the same number.

However, other attractors are possible, in which there is a higher degree of order. A cloud of gas in outer space will tend to contract through the action of gravity. A person sitting on a well-made chair, experiencing steady gravity, will probably not fall

[2] One way of describing this is the idea known as quantum decoherence. This refers to the interaction of the statistical probabilities of particles, rather like many ripples inter-combining on a pond. (Albrecht 2001). This is one way of solving the famous problem of "Schrödinger's cat" (Zurek 2003).

over. A brick wall will tend to stay in its well-ordered state. Except for the example of gas contracting under gravity, these unlikely states will tend to have been arrived at by the creation of greater disorder elsewhere. They are called open systems, because energy is entering into them from the outside, which is permitting alteration of probabilities. The smaller the system, however, the more likely the appearance of order at random. It is not so unusual to throw two dice and get doubles.

To give another example, it is statistical mechanics that makes the game of golf possible. A long shot will be more difficult to direct precisely than a short shot, generally speaking. The influence of wind and other factors adds up over time, and small initial errors in the trajectory or spin of the ball become progressively larger. If statistical mechanics did not apply, and somehow the ball always entered the hole in one shot, no-one would play golf; indeed, the game never would have been invented. Human activity is necessarily aimed at managing probability, in some respect. If probability cannot or need not be managed, there is no motive for action.

When the terms “statistical” or “statistical mechanics” appear in this thesis, this is the general intention of those terms. I am referring to the emergence of probability for the system in question from the combined effects of changes in the system and its environment. These terms should not be taken as implying the exclusion of models that do not use points; statistical mechanics is possible using waves or fields, for example. No absolute background is required for statistical mechanics, as I intend the term. This is required for full compatibility with relativity theory and quantum field theory (which use fields instead of points).

1.4.4 Quantum Darwinism

Some ideas in this philosophical scheme are similar to those in the recent school of thought known as "Quantum Darwinism". (See for example Blume-Kohout and Zurek 2006, 2007). However, I have arrived at a position similar to Quantum Darwinism by starting from a philosophical perspective, rather than a quantum mechanical one. I only became aware of this similarity in the final stages of this thesis, after its content had been finalised. However, I had been influenced by some of the earlier writings on quantum decoherence of the main proponent of Quantum Darwinism Wojciech Zurek, former student of John Wheeler (one of the founders of quantum physics).

Quantum decoherence uses the idea of einselection, short for "superselection by the environment". Superselection, in this interpretation, is the transition from quantum probabilities to classical probabilities (the issue highlighted by the thought experiment "Schrödinger's cat"). "The principle of superposition applies only when the quantum system is closed. When the system is open, interaction with the environment results in an incessant monitoring of some of its observables. As a result, pure states turn into mixtures that rapidly diagonalize in the einselected states… Their predictability is key to the effective classicality" (Zurek, 2003:729).

Quantum Darwinism takes the principles of statistical mechanics down to the quantum level. "To exist, a state must, at the very least, persist or evolve predictably in spite of the immersion of the system in its environment. Predictability is the key to einselection" (Zurek 2007:24). This selection can be compared with the genetic algorithms used in biology. "Some quantum states are resilient to decoherence. This is the basis of einselection. Using Darwinian analogy, one might say that [einselected] states are most 'fit'. They survive monitoring by the environment to leave 'descendants' that inherit their properties… Save for classical dynamics, (almost) nothing happens to these einselected states, even though they are immersed in the environment." (Zurek 2003:718).

My approach defines some terms differently. For example, Zurek follows information theory conventions that define information in terms of order and entropy in terms of loss of information to disorder. In this thesis, I define information as change measured at a location by an observer, without reference to the level of order of that change; and entropy as change in a system according to statistical mechanics, which will be a tendency towards disorder, broadly speaking, discounting the effects of gravity. I further divide information into relevant and irrelevant information for the observer: ordered information will tend more towards relevance than disordered information, in a functional context. (For example, speech tends more to relevance than white noise, in most situations.) Details on the concept of relevance are given in the next chapter. My definition of objectivity is also slightly different to Zurek's: I define objectivity in terms of functionality, while Zurek uses agreement among independent observers. The two definitions are quite similar, however, and I am pleased to have found some support for my way of thinking in Quantum Darwinism, albeit at a late stage in writing this thesis. I will return to the topic of objectivity below.

1.4.5 Classification of topics on a topological basis

My three categories of the Physical Category, Relevance Category and Signal Elements Category can be considered as sets of ideas defined according to the aspects of systems theory that each addresses.

The Physical Category is mostly concerned with explaining the physical basis of probability and the flow of information, and so mostly contains ideas relating to physics in some way. These ideas are also connected with explanations of how complexity comes about in the first place. The Physical Category also covers the mathematics of order and disorder (the right balance of the two being necessary for complexity), thresholds (the edges of attractors that move a system from one phase to another) , feedback and nonlinearity.

The Relevance Category is for ideas that relate to the consequences of stability, especially metastability (the persistence of a system that is relatively unlikely in terms of the degree of order of its components, like a table or a whirlpool; being due to the action of an open system, or possibly chance, for very small systems). Of examples of metastability, the Relevance Category is particularly concerned with homeostatic systems. Homeostatic systems are self-organising systems that are robustly stable due to the combined interaction of many sub-systems. Homeostatic systems are necessarily so large that they must always owe their order to their being open systems. There is no possibility of a homeostatic system arriving fully formed through chance. It will either arise from evolution of some kind, or be arranged by another open system (for example, a computer programmer creating a homeostatic simulation of the ups and downs of fox and rabbit populations). The Relevance Category also covers game theory, which is a way of looking at the interactions of stable systems as they compete for resources to achieve various goals.

The Signal Elements Category covers the relationship between the structure of stable systems and communication between them. I take the position that communication *per se* first arose in a game-theoretic context of functional strategies in the course of evolutionary survival. Through homeomorphism, it is possible for organisms to model systems in the environment abstractly, in many different ways, and to use relevant information from those models to direct their behaviour. These abstract systems of representation can be used for communication in a game-theoretic context, but they are not necessarily tied to whatever it is they were first used to represent, and their structure can evolve independently through association and extrapolation in the context of their own internal logic. This is especially true for we humans, whose consciousness is very much concerned with collation of different modes of representation.

Different formal schemes can interact and enter into a feedback relationship: and formal schemes and practical goals can also develop feedback, with the evolution of a formal scheme resulting in changes in practical goals, and vice versa. For example, scattering of photons from objects provides a flow of detailed information on the current disposition of the environment. It is often relevant to be able to distinguish different wavelengths of light, leading to recognition of colour in the course of biological evolution. (The Signal Elements Category is a subset of the Relevance Category.) There may then follow an evolutionary process that results in organisms using the ability to recognise colour to signal danger or suitability for mating, or to send other relevant information. As colour develops its own system of associations, a shade of blue might come to represent for the right observer a particular era of French interior design; and for a synaesthetic person, the grammar of colour association may interact with that of numbers, enabling great feats of mental calculation (Ramachandran & Hubbard 2003).

Formal schemes within the Signal Elements Category are capable of nonlinearity, which is essential for useful description of the nonlinear phenomena when constantly encounter. For example, an infinite number of different sentences could theoretically be constructed using a language with a finite number of words. However, perfect description of physical phenomena is rendered impossible by the nature of information, due to factors such as Heisenberg's uncertainty principle and the extreme complexity of nonlinear, multidimensional systems.

As mentioned above, this thesis falls into the Signal Elements Category. However, I will leave further discussion of this point until that chapter is reached.

1.4.6 Specific relation to other areas of philosophy

Topics discussed in the Physical Category will be of interest primarily to metaphysicians. Those in the Relevance Category relate to mainly to philosophy of morality, and philosophy of mind. Topics in the Signal Elements Category (including the self-referential topic of “what is it to classify topics?”) are relevant to a number of branches of philosophy, including logic, philosophy of language, philosophy of art, philosophy of mathematics, philosophy of music, and philosophy of science.

One aim of this thesis is to begin to explain a way of unifying these diverse areas of philosophy with each other and with science. Philosophy that takes relativity theory, quantum physics and systems theory into account ought to thereby gain robustness and explanatory power. For example, a philosophy of time that can incorporate the concept of space-time ought to be more useful than one that cannot. Having a good theory of how complexity works helps understand and explain the physical basis of the topics in the Relevance Category and Signal Elements Category.

2. The Physical Category

> Physics doesn't tell us how nature is; it only tells us what we can say about nature.
>
> Markus Aspelmeyer (Brooks 2007:33)

The Physical Category contains topics such as entropy, probability, order and disorder, gravity, time, information and complexity. Of these topics, perhaps only time is a traditional topic of philosophy, at least from the Classical period to the end of the nineteenth century. But the middle of the nineteenth century saw two developments that were to revolutionise science: thermodynamics and the theory of evolution by natural selection. Thermodynamics permitted relativity and quantum physics, while Darwin's theory led to modern biology, as well as to other applications of the basic principle, such as game theory and expert systems (neural networks and other control systems capable of learning). Systems theory attempts to incorporate both of these branches of modern science, by basing principles of organisation on a physical foundation. Using systems theory to do philosophy means accepting some form of physicalism, although one need not adopt what Daniel Dennett pejoratively labels "greedy reductionism" (1995).

One of the most important foundations of the Physical Category is that the universe is a closed system; and that our existence within that system should be taken account of when attempting to explain both direct observation and formal models. This allows the Physical Category to include topics in relativity theory and quantum physics.

Indisputable proof that the universe is a closed system is difficult to find.

Physicist Lee Smolin, one of the founders of Loop Quantum Gravity, speaks plainly: he defines the universe as "all there is", then says that "the first principle of cosmology must be 'There is nothing outside the universe'" (Smolin 2000:17). He goes on to say, "This first principle means that we take the universe to be, by definition, a closed system. It means that the explanation for anything in the universe can only involve other things that also exist in the universe". There is more to the question of whether the universe is a closed system than Smolin lets on, but in the end I agree with his formulation.

In relativity theory, things are much simpler if the topology of the universe is finite, yet unbounded (as the surface of a ball is, for example), as Einstein pointed out as early as 1917 in "Cosmological Considerations on the General Theory of Relativity". However, the global topology of the universe is undetermined in general relativity theory: "…since the Einstein gravitational field equations are differential equations, they only constrain the local properties of space-time but not the global structure of the Universe at large" (Aurich 2005:1). The overall topology of the universe "depends on the way the total energy density of the Universe may counterbalance the kinetic energy of the expanding space" (Luminet 2006:107). There are three possibilities: we may live in a flat universe; it may curve like a sphere or a similar shape such as a dodecahedron (this is called a closed universe, not to be confused with the closed *system* universe); or it may be hyperbolic, as is a saddle with a saddlehorn (this is called an open universe, but likewise does not imply an open *system*). Of the three possibilities, only the closed universe need be finite. In terms of geometry, "flat (Euclidean) or negatively curved (hyperbolic) spaces can have finite or infinite volumes, depending on their degree of connectedness" (Luminet 2006:108). Scientific research based on astronomical data has not given a conclusive result as to the topology of the universe, although if it is curved positively or negatively, it seems the curvature is not strong. According to some cosmologists, the wavelengths of density fluctuations in the temperature of the cosmic microwave background radiation, as measured by the Wilkinson Microwave Anisotropy Probe (WMAP), are not compatible with an infinite universe (Luminet et. al 2003).

If the universe is finite, we can be confident that it is a closed system, with no energy entering or leaving. If infinite, the question becomes more difficult: perhaps the regress that arises in observing observation might somehow cease to be a problem. But in any case, our universe is effectively finite for observers within it. The observable universe is finite, given the relativistic constraint that information has only had a limited amount of time to propagate since the Big Bang.[3] Going beyond the observable universe, it seems that a finite, unbounded universe is the most likely, from astronomical observation; but regardless, for we observers the universe is certainly a closed system, and so Smolin's formulation is acceptable.

The closed system universe has various implications. An observer within a closed system, who is part of the system being observed, can never completely describe the whole system. The universe is always observed from a particular context. Knowledge requires physical propagation of change from an event to an observer, which takes time. Formal models can serve as guides to observation, but we should remember that such systems can include assumptions of perfect knowledge that are not in fact possible. Smolin gives two further principles: "that every observable in a theory of cosmology should be measurable by some observer inside the universe, and all mathematical constructions necessary to the formulation of the theory should be

[3] Some cosmologists believe it is possible that the observable universe is larger than the universe itself (Luminet et. al 2003). This could be the case if parts of a finite universe have had time to cover its whole volume, like an ant walking around a soccer ball and arriving back where it began.

realizable in a finite time by a computer that fits inside the universe" (2000a). These formulations for cosmology are compatible with the idea in information theory that "information is physical", as described for example by Rolf Landauer (1991). Physical constraints on information propagation are one way in which the closed nature of the universe has consequences for observation.

This approach can be traced back to Hugh Everett's idea of the relative state (1957), which led to the "many worlds" interpretation of quantum physics (1957). It has been further developed by physicists such as Carlo Rovelli in his relational interpretation of quantum mechanics (1996) and Wojciech Zurek in his explanation of quantum decoherence (2003), as well as appearing in the approach to quantum gravity theory of Smolin and associates such as Chris Isham (2000).

These constraints placed upon observation by the closed system universe will recur throughout this thesis.

2.1 Entropy

Much as we expect that, under normal circumstances, when we drop a stone it will fall downwards, so we also expect that if we drop a hot stone into a bowl of cold water, the stone will cool down, and the surrounding water will heat up. As descent of the stone is due to gravity, so the warming of the water is thanks to entropy: that is to say, entropy is the term that scientists use when measuring such processes. The term was coined by the physicist Rudolf Clausius in 1865, the rise of steam power in the nineteenth century having increased scientific interest in the dissipation of heat.

The first step on the road to the scientific concept of entropy was Gottfried Leibniz's investigation in the late seventeenth century into what was later called the conservation of kinetic energy, for which he used the term "*vis viva*", or living force.

These theories were refined over the years, and *vis viva* was replaced by the term "energy" early in the nineteenth century. Although the term "energy" is difficult to define in a concrete way (for example, one can define energy with reference to work, and then define work with reference to energy), it came to be a useful component of scientific theory through the discovery that there is a measurable property (called "energy") that remains constant when any change occurs. The two broadest categories of energy are kinetic energy, which is associated with movement, and potential energy, which is associated with the distance between things that are connected by a force such as gravity. (The general theory of relativity succeeds in bringing overall unity to these seemingly disparate concepts of energy.) Dropping a stone starts a conversion of potential energy to kinetic energy. One might define energy as the capacity to cause change.

By the 1840s, these investigations had resulted in what came to be called the first law of thermodynamics, that energy can neither be created nor destroyed. To return to my earlier example of a stone heating water, first the stone must itself be heated, perhaps by burning wood, which has stored energy in the course of its growth, essentially from the sun, which itself owes its energy to gravity. In the course of this process, no energy is created nor destroyed. However, energy is constantly being dissipated. That is to say, the transfer of energy is never perfectly efficient. We make use of this dissipation in warming the cold water with the hot stone; but when we earlier heated the stone on the wood fire, a great deal of the energy of the fire would have been dissipated into the cold air, and hence unavailable for our purpose of heating the water. Study of this inefficiency, spurred by the demands of steam power, eventually led to the introduction and acceptance of the term "entropy".

At around the same time as the conservation of energy and the inefficiency of energy transfer were pinned down scientifically, it was discovered that heat is a kinetic process, related to the movement of the molecules. This meant that the dissipation of energy into heat (which is to say, increasing disorder following entropic probability) could be described in terms of statistical mechanics, and entropy came to be much better understood, its definition became much broader, and entropy became applicable to topics outside of the behaviour of heat.

This is not to say that one can unquestioningly rely on traditional statistical mechanics concepts like "temperature is mean kinetic energy". That formulation is useful at a particular scale: it is very suitable for purposes such as building steam engines. In the philosophical scheme which I am outlining here, "statistical mechanics" is ultimately founded on the idea of quantum decoherence. (For an excellent overview of the connection, please see Zurek 2003.)

2.1.1 Measuring entropy

The abstract nature of the concept of energy might be seen as a potential problem. It seems to have a certain vagueness about its definition, which seems also to be the case for the definitions of entropy and information. All are defined in different ways in different scientific disciplines, yet this lack of consensus does not seem to cause any practical disadvantage in any of the three cases. In fact, the vagueness in all three definitions results from butting up against limitations inherent in the process or activity of measurement. Energy was discovered as a constant figure that was conserved through various changes in measured phenomena. When measured, it is always abstracted from some actual phenomenon. Energy might be said to be a behavioural characteristic of what is being measured. It must have a context, and a measurement of its level at a particular instant (translated into arbitrary units) is useful for many purposes, but not wholly descriptive of that context. Much the same can be said for entropy and information, as I will mention later. In this thesis, I will not be focussing on the measurement and mathematics of these concepts, but rather I will be looking at contexts and consequences.

In my view, a formula represents a mathematical perspective with many hidden assumptions. That is not to say formulae are useless. Indeed, “a useless formula” is probably an oxymoron. Formulae always have specific uses, even if only as elements in larger theories, or as a provisional way of getting at some ill-understood phenomenon. That is precisely why a formula represents a certain perspective, and the assumptions of that perspective are often hidden and hard to extract. For example, one definition of entropy is heat over temperature. That definition is very useful in calculating heat flow, but threatens a very long and unproductive diversion if one were to fully describe the perspective it represents.

2.1.2 Entropy and probability

That said, I do wish to make use of one formula straight away, because the perspective that it represents is useful to my argument.

It was Ludwig Boltzmann who first had the insight that entropy was related to probability. One of his best known formulae (it is carved on his tombstone) is $S = k \log W$. S stands for entropy, and W stands for the number of ways a system can be arranged. k is a tiny constant to balance out W, which is usually an enormous number, thanks to the complexity of most actual systems. The log is required because S is additive while W is multiplicative (see von Baeyer 2004:96), but I have a suspicion that the log may be related to what is known as the Bekenstein Bound, the association of entropy with surface area that is used in the physics of black holes (I will return to this topic in section 2.4.5.2.7).

What this means is that in the case of the hot stone in cold water, at the system formed by the boundary of the stone and the water, there are a lot more ways for the system to have an even temperature than to have an extreme difference of temperature, much in the way that seven is the most likely number to total when throwing two dice. Ways where the system loses heat (energy of molecule movement) on the cold side and gains it on the hot side are even fewer. Therefore, over time, the stone and the water will tend to come to an equilibrium, with no obvious heat difference, barring outside interference. Hence the second law of thermodynamics: the entropy of a closed system tends to increase towards a maximum.

Note the immediate entry of the term “time” into the discussion. Entropy and time are closely related, as I will discuss in section 2.3.1. Entropy can be measured in various units (even bits, the unit of information), but it is always measured in a physical and temporal context. The concept of entropy shares with energy and information a necessity for a specific context of measurement, and this limits the philosophical usefulness of the diverse techniques for measuring entropy numerically. Entropy is not a thing, but a tendency, or, as I put it in the case of energy, a behavioural characteristic of what is being measured.

The probabilistic nature of entropy means that the second law of thermodynamics is not quite as iron-clad as the first. Given a very small system, it is possible for entropy to decrease spontaneously. But for the overwhelming majority of systems, the chances of entropy spontaneously decreasing are so incredibly small as to make the law inviolable for all practical purposes.

Boltzmann’s formula is an idealisation. The number of ways a system can be arranged is another way of referring to the “phase space” of the system. But what is clear in mathematics is not so clear in the physical world. We can detail the phase space of a mathematical model of a system, but if we try to write down all the states of an actual physical system, we will run into limits such as quantum uncertainty. The phase space of a physical system is always an abstraction: not only are some possible phases never instantiated physically, but we cannot be absolutely sure which phases *have* been instantiated, and therefore if it makes sense to talk of "instantiation" at all. Is that not giving undue priority to the model over the physical?

2.1.3 Entropy and order

Entropy can be characterised in terms of increased disorder, at least when the action of gravity on the system is sufficiently small. When a hot stone is dropped into cold water, creating a system with one area of very high heat and one area of very low heat, that system was more ordered than as it will end up after being left for an hour. And in classical information theory, entropy is associated with signal noise, which can be seen as a form of disorder (although noise and disorder are not identical, in my view), and information is measured as the log of signal to noise, in bits.

We know order when we see it: a child would say that a brick wall was more ordered than a clutter of strewn bricks. But how do we describe it in technical terms? And what is the connection between probability and order? A brick wall is more likely to become a pile of bricks as time passes, rather than the opposite: hence our efforts to preserve historic buildings.

When we see order, we can make an assumption that somehow the second law of thermodynamics is being circumvented. In other words, that energy has entered or is entering the system from the outside. When we see a brick wall, we can assume that someone built it, and when we see a snowflake, we also look for energy coming in and being put to work through some process (self-organisation, in that case).

The best way to describe order is in terms of patterning. Patterning is one of the major topics of this thesis. Here I will simply say that pattern is related to the ease of describing the relationship among a given set of elements.

Ease of description is another way of putting the idea of informational compressibility. This compressibility is of great practical utility to living things, and has an important role in many inanimate processes, also.

Order is less likely than disorder, for systems where the effect of gravity can be ignored, and also barring outside interference. As the heat of the stone dissipates into the water, the system loses its simple pattern of a hot area surrounded by a cold area, it becomes more disordered, and we know less about the precise situation of the molecules making up the system. Conversely, few of the possible ways of arranging a pile of bricks result in a wall. If the wall is extremely well-ordered in its construction, with every brick edge aligned with many others, there are even fewer ways the bricks could be arranged.

To put the point in more abstract terms: If one assumes a system made up of many individual elements, which are randomly shuffled at regular intervals, over time there will be relatively few states that are relatively easy to describe. Disorder will be more common than regular patterning. Therefore, when we see order, we are fairly safe in making the assumption that energy has entered the system somehow, and has been used to alter this probability.

We can also assume that, when we see order, it has been obtained at the expense of creating disorder elsewhere. The workers putting up the wall will have eaten food and given off heat in the course of their labours. As with heating a stone in a fire, the transfer of energy is always inefficient. Given that the universe is a closed system, its overall entropy should be increasing towards a maximum. Nonetheless, within a limited area the second law of thermodynamics has been circumvented, since we are looking at an open system rather than a closed one. This localised management of entropy is the basis of life.

2.1.4 Conceptual problems with entropy

When Boltzmann formulated his concept of entropy in terms of the number of ways a system can be arranged, he also associated entropy with our lack of knowledge of the state of a system. It appeared to Boltzmann that the more we know about a system, the more we know what will happen to it, and that this reduces the number of ways in which the system can be arranged. As we come to know more about a system, the entropy of that system would therefore decrease.

This approach is also found in classical information theory, in which maximum entropy implies minimum information. If we identify information with order and entropy with disorder, the noisier a signal becomes, the less information it can convey to us. As noise increases, we know less about what is going on.

This element of subjectivity raises serious problems for information theory. How can a property of a system go up or down according to our knowledge of it? And if we are investigating noise on a signal line, and send an arbitrary, regular signal pulse and pay attention to the noise surrounding it, has noise magically become information and information become noise? If the noise is ordered in some way (perhaps chaotically), is it still noise? Can noise have its own noise if its ordering is not perfectly regular?

The classical definition of information in terms of communication of meaningful signals, originally proposed by one of the founders of modern information theory, Claude Shannon, has been superseded by broader, more useful definitions. It is much too simplistic to identify information with order, and to view entropy (the tendency towards disorder in closed systems) as its enemy. In my view, both aspects of this problem of subjectivity arise from putting too much faith in numerical measurement. Entropy should not be thought of as a property, but as a tendency within a specific context. The above problems directly relate to the nature of information and observation. I will look at limitations due to the nature of information later in this thesis.

2.1.5 Summary

A hot stone is dropped into cold water. As time passes, the overall state of the system tends towards a uniform-temperature equilibrium, thanks to statistical mechanics. The system becomes more disordered and harder to describe, because information describing the system cannot be so easily compressed. A group of workers assembles a wall. If we choose to look at the system consisting of the bricks, then we observe a system moving farther from equilibrium, becoming more ordered. The wall is in a "metastable" state, with its components arranged with a degree of order that is extremely unlikely to have been arrived at randomly.

This is how things behave in our universe, and the reasons for this behaviour are to be found in cosmology. The essential points that I wish to emphasise at this juncture are the relationship between entropy, probability and disorder; and the relationship between order, patterning and informational compressibility.

If energy can be defined as the capacity to cause change, then entropy might be defined as the greater probability for that change to result in disorder, in a closed system, with caveats on the influence of gravity. However, living things and inanimate processes often increase order within limited boundaries, although in the wider context order will be sacrificed elsewhere. The ultimate reason that order increases in parts of our universe is to be found in the nature of patterning, and the source of the energy that permits it is gravity.

2.2 Gravity

Gravity has been identified by Albert Einstein as the curvature of space-time. As the physicist John Wheeler famously put it, "Matter tells space how to curve, space tells matter how to move", which may perhaps bring to mind the division of energy into the broad categories of potential energy and kinetic energy. In quantum field theory, gravity can also be explained in terms of the action of theoretical particles called gravitons. However, this explanation breaks down at very small distances, and there are currently at least three competing theories addressing the subsequent problem of quantum gravity. In this thesis I will not venture very deeply into scientific explanations of gravity, but rather look at the connections between gravity and entropy.

Does a cloud of gas floating in space have high entropy or low entropy? On the one hand, it is disordered: the molecules are randomly distributed, and detailing their arrangement on a fine scale would take a lot of information, more than a system of the same size consisting of a regular lattice of gold atoms, for which the description could be more easily compressed. One might therefore say it has a high entropy. On the other hand, the gas has a uniform temperature, and on this broader scale is therefore easy to describe. As for the ways in which it can be arranged, over time it will be acted upon by gravity, and become more ordered, perhaps even becoming a cluster of stars. It is therefore not in equilibrium (it is likely to change its arrangement) and one might say it has a low entropy for that reason.

In most examples, such as the hot stone in cold water, we can simply leave gravity out of the picture, since its influence on small systems is so weak. At larger scales, it becomes more significant, which has consequences for numerical measurement of entropy in the course of scientific investigation. We could therefore redefine entropy for gravitating systems, with a disordered state being seen as low entropy, and a denser, more ordered state as high entropy.

There seems to be some theoretical confusion here, but this is just another example of the effect of choices made when deciding what properties of a system to take into account. The ways in which a system is likely to become arranged (its entropic tendency) are vitally dependent on the specific properties of the system under consideration, but for practical purposes the gravitational properties of many systems can be ignored. When we find we must take gravity into account, since it has a significant influence on the ways a system is likely to become arranged, our conception of entropy must take account of that.

Scientists know from observation that the cosmic microwave background radiation left over from the Big Bang is in equilibrium (maximum entropy), if gravity is ignored. However, when gravity is included, the consensus among physicists such as Roger Penrose (1979) and Paul Davies (1999:62) is that one should say the universe began in a state of low entropy. This preserves the second law of thermodynamics: the action of gravity has not decreased the entropy of the closed system of the universe, but increased it. The reasons for this initial low-entropy state are debated.

We know that order in the universe has increased since the Big Bang, with gravity creating stars from gas, and we know that the universe is a closed system, no energy having entered from the outside, at least not since the Big Bang, and perhaps not even then. Earlier, I said that when we see an increase in order, we can assume that energy has entered the system, but gravity provides an exception to this assumption. The reason for this exception is that gravity has what is known as negative energy. The negative energy of gravity balances out the positive energy of the contents of the universe, quite possibly adding up to zero.

A stone an infinite distance from the Earth would have zero gravitational potential energy: it would not be affected by gravity from the Earth at all. Yet, a stone on the top of a mountain has more potential energy than one in a valley – to move a stone away from the Earth, by lifting or throwing it, requires an input of positive energy. The only way to reconcile these two points is to say that the gravitational potential energy well of the earth represents negative energy. It is the interplay of the negative energy of gravity, and the positive energy of matter and radiation, that produces the order we observe in astrophysical phenomena such as stars and galaxies.

Assuming Alan Guth's theory of the inflationary universe (1997), since "[t]he cosmological expansion is a manifestation of the *gravitational* activity of the universe" (Davies 2005), the matter and radiation of the universe become an open system within a larger closed system. This is one way of visualising the ability of gravity to permit an apparent decrease in entropy, if entropy is identified with disorder. However, when it comes to picturing the inflation of the universe, we must take great care that we do not oversimplify things by relying on metaphors of expanding balloons and rising cakes. The "inflationary universe" is also a mathematical perspective with hidden assumptions.

The point at issue is covered by Wheeler's pithy aphorism quoted above, "Matter tells space how to curve, space tells matter how to move". The way matter moves under the influence of gravity is to group together. The way space curves means that this attraction is stronger at shorter distances. The effect of gravity is to provide ways (Boltzmann's term W) in which systems can become more ordered, and this results in a difference from the typical entropic paths we see in systems where gravity can be ignored. While the self-organisational process seen in snowflake formation (for example – self organisation will be covered in a later chapter) also provides ways in which a system can become more ordered, the difference with gravity is that its characteristic negative energy makes it a "free lunch" in terms of the ultimately closed system that is our universe, whose total energy remains probably at zero.

The role of gravity in creating order, for example by condensing a cloud of gas, has consequences for talking about "an increase in entropy" in numerical units. Under my definition, entropy is a consequence of probabilities and outcomes in statistical mechanics. It is convenient to talk about an increase in disorder as being an "increase in entropy", since gravity can usually be discounted, being a relatively weak force (it is easier to fly than to split the atom). And of course the effects of gravity do not *always* result in an increase in order! But ideally, entropy should not be used as a synonym for disorder. One should say "an increase in disorder", even though that disorder results directly from the entropic state at that time (the probabilities due to statistical mechanics).

I cannot give a more compact account of the relationship between gravitation and order than Paul Davies, and so I will quote him in full.

> "Looking at the universe as a whole, the initially smooth distribution of gas coughed out at the big bang slowly turned into splodges of hotter and cooler gas, and eventually arranged itself into shining proto-galaxies surrounded by empty space. The proto-galaxies in turn formed glowing stars. The expansion of the universe assisted the escalating thermal contrast: as the

> universe expanded, its background temperature dropped, and the hot stars were then able to radiate more vigorously into the cold space. The upshot of these gravitational processes was that an entropy gap opened up in the universe, a gap between the actual entropy and the maximum possible entropy. The flow of starlight is one process that is attempting to close the gap, but in fact all sources of free energy, including the chemical and thermal energy inside the Earth, can be attributed to that gap. Thus all life feeds off the entropy gap that gravitation has created. The ultimate source of biological information and order is gravitation." (Davies 1999:64)

A large part of this thesis concerns how arrangements that are relatively improbable for a randomly changing system become more probable in both theory and everyday lived reality: in other words, how patterns arise. When we see order around us, we should be able to trace back to gravity the energy needed to get the probabilities moving in that way, in the face of the general tendency towards disorder. (One other source of energy that could potentially be used in establishing order is dark energy. But since it is not well understood, and could even be an error introduced by a mistaken assumption as to the curvature of the universe, I will not discuss dark energy here.) In most or perhaps all cases of order on Earth, we can trace the energy input that allows the second law of thermodynamics to be circumvented either to the Sun, or to the internal energy of the Earth, both of which are directly attributable to the action of gravity.

The concept of gravity will not itself be prominent in this thesis. But for the sake of establishing a sound foundation for my arguments, it is important to note at the outset that there is an identifiable energy source that enables the manipulation of entropy, the latter being one of my major themes.

I said earlier that scientific formulae and their terms include assumptions that are often hidden. This is no less true for gravity, and I will touch on a theory that suggests the existence of gravity may be a matter of perspective in section 2.4.5.2.7.

2.3 Time

The next in this set of four interrelated concepts is time. Our understanding of time has been greatly advanced by relativity theory. As physicist Lee Smolin puts it, “Neither space nor time has any existence outside the system of evolving relationships that comprises the universe” (2000:24). Time and space are not independent in relativity theory. Spacetime curvature is a kind of energy (capacity for change), and thus a kind of mass, and the relationship between spacetime curvature and physical bodies is nonlinear.

We naturally divide time up into the past, the present and the future. However, in our normal usage of these terms we ignore the implications of relativity theory. (In relativity theory, two events that occur simultaneously as measured by one observer will not be simultaneous for another observer moving relatively to the first, for example.)

Our common-sense idea of the present is particularly problematic. I will address the problems with our understanding of the present below, in my discussion of consciousness.

If time is identified with change, then it should be seen why time shares a certain vagueness about its definition with entropy, gravity and information. Time is not a thing, but becomes apparent only through observing the behaviour of things.

2.3.1 Arrows of time

It seems to us that time moves from the past to the future, and that this process is irreversible. The cosmologist Gerald Whitrow identified three arrows of time (1972): cosmological, historical, and thermodynamic. These are three ways of looking at the same thing, this phenomenon of temporal irreversibility. Here I am particularly concerned with the historical arrow of time, which is specified in terms of the nature of information, and the thermodynamic arrow of time, which is concerned with entropy. The cosmological arrow of time (which looks at the relationship of time with the expansion of the universe) is not directly relevant to my argument, except insofar as one can view cosmological expansion as permitting the existence of entropy, as I have already briefly mentioned, and therefore the thermodynamic arrow of time.

2.3.1.1 The thermodynamic arrow of time

The thermodynamic arrow of time can be stated as follows: the probability of the entire universe reverting to a state that is identical to an instantaneously previous state is infinitesimal. The idea of an "identical state" is problematic, given limitations to measurement, not to mention the impossibility of measuring things if time *were* to run backwards. Nonetheless, insofar as the relationships between matter and radiation move from one state to another in our expanding universe, there is essentially no chance of this process reversing.

Time is intimately related to probability, to the ways in which things can happen in the future, and therefore to entropy. Given an instantaneous state of the universe as extrapolated from information received at a point in space-time (there being no "instantaneous state of the universe" except as measured from a frame of reference), there are many possible states of the next instant, each with a certain probability. One way of looking at time is as the roll of the dice to determine what state comes up (with a total of seven being more likely for two dice than a total of twelve). Having the thermodynamic arrow of time reverse would be as if one threw an unimaginably large number of dice, vastly more than could be manufactured using all the matter in the universe, and every single one came up with the same number, and that were to happen over and over again. It is essentially forbidden by statistical mechanics.

The various probabilities of the states of a system can be pictured as what is known as “phase space”. One way of imagining this space is as a landscape, with points “downhill” from the current point being more likely (a point represents the entire state of a given system at a particular time), although this is a simplification of the dimensions that are actually involved. Deep holes in the landscape are attractors. One might imagine a leaf on the surface of a turbulent river: there are locations where, if the leaf strays too close, it will be unlikely to escape. Another example might be the solar system, with the space-time curvature resulting from the gravity of the Sun, the planets, the asteroids, and so on, representing attractors. If phase space is visualised as a landscape, time can be interpreted as distance on that landscape, and movement as change in the system.

Earlier, I gave an example of an abstract closed system, changing arbitrarily from one moment to the next. I said that regular (compressible) patterns of the system elements at a given moment would be rarer than irregular ones. With the introduction of phase space, new patterns become discernible; patterns across time appear, in addition to patterns representing the spatial arrangement of the elements of the system at a given moment. If an incompressible pattern happens to turn up twice in succession, it has become part of a regular pattern across time.

Regular patterns across time will be relatively rare if the next state of a system is in no way determined by the previous state. However, if change in the system from moment to moment is not arbitrary, but deterministic in some way, then there will be attractors for the system that do result in regularity over time, even for a closed system. For now, I will simply note that time provides an extra dimension for patterning, but I will return to the discussion of patterns below.

If one were to say that time is the observed resolution of probability, and that entropy describes the ways in which a system is likely to change, the connection between entropy and the arrow of time should be clear. To return to my earlier example of a hot stone in cold water, time appears in the action of entropy, which in this case is the probabilistic dissipation of heat into the water. Time is the same thing as the change in the relationships among the elements of the system, which follows probability. Change is governed by statistics, and I will look at some of the implications of statistical mechanics for the nature of time in the next section.

2.3.1.2 The historical arrow of time

The historical arrow of time conceives of irreversibility in terms of the accumulated effects of information received. Thanks to statistical mechanics (the specific flow of entropy, in other words), change in one part of a system causes a cascade of further changes through time and space, under most circumstances. This cascade of change is identical, in my view, with the transmission of information, and this is why information is not the opposite of disorder, nor of entropy, which are two common, related misunderstandings. (I will focus on the nature of information in section 2.4.)

If one looks at the surface of a table, it will normally be seen to have suffered dents, nicks, abrasions, and so forth, by random impacts over time. In some sense, it carries a record of certain changes within the system made up of the table and its environment. A police detective might even use a given dent to reconstruct an event that took place during a crime. The surface of the table tells us a little bit about the past, but we can only guess what will happen to it in the future. This is an example of the historical arrow of time: information accumulates over time.

One can use some features of the nature of information to make a case that the arrow of time is (to coin a phrase) computationally inevitable for any observer (as we normally understand the term).

The detective examines the surface of the desk, and finds the graze of a bullet. Changes in the system have resulted in the detective gaining information about previous events. How sure can the detective be that the graze occurred in the course of the crime she is investigating? She will assign a probability to the truth of her conclusions, based on a variety of evidence, and indeed truth must always be probabilistic for any observer. The flow of entropy (the thermodynamic arrow of time, in other words) means that the past cannot be perfectly reconstituted and examined afresh. And while we assume that when we look at things, we observe them as they are *now*, as Lee Smolin puts it, "…when you look around you do not see space - instead, you are looking back through the history of the universe. What you are seeing is a slice through the history of the world." (2000:64). The delay caused by the time that information takes to reach us, in many cases, is just noise: it does not significantly affect us. But nonetheless, information is always information *about* the past.

What about the future? Will there be another bullet-graze in the desk tomorrow? It seems fairly unlikely, under normal circumstances, but we can't be sure. The universe is just too complex for us to predict the future state of the desk with absolute certainty. And besides the brute complexity of the situation we find ourselves in, there are other limitations to predicting what will happen that mean predictions of the future state of the universe can never be perfect. I will briefly outline some of those limitations in the following four sections.

2.3.1.2.1 Self-organised criticality

One special example of complexity is what is known as a "self-organised criticality", a term coined in Bak et al. (1987). Thanks to the landscape of phase space, and its attractors, many systems have thresholds where they experience large amounts of change over relatively short periods of time. For example, take a stone on a hillside. With the heating and cooling of the day, a stone that has sat in the same place for a year might suddenly come loose and roll away. Now, in a system where many such threshold-bearing elements are able to interact and transfer information from one to another, it becomes exponentially harder to predict the extent that any one change will propagate through the system. The more stones on the hillside, the more difficult it is to predict how big an avalanche that falling stone will result in. It may stop soon, or it may bring the whole hillside down. We can say that small avalanches are more common than big ones (the distribution will follow a power law), but in a given case we cannot predict the pattern beforehand.

The flow of entropy that accompanies the process of measurement, which inevitably results in errors, coupled with the incredible complexity of such systems means that they are impossible for us to model. The phase space is just too complicated, incredibly spiky in many dimensions. We cannot gather information to a degree of accuracy that permits prediction of the future of the system, which is a real problem in guessing the extent of the next earthquake, forest fire, traffic jam, or market crash, for example.

2.3.1.2.2 Chaos

Another special example of complexity that cuts us off from the future is chaos. (Chaos, as the term is used in this thesis, refers to deterministic aperiodic systems, rather than simple disorder.) If a system has the right number of elements, and furthermore if changes are fed back as input into the system, then what are known as "strange attractors" can arise within the phase space of that system. The system is deterministic: its previous state determines its current state. However, if it falls into a strange attractor, it will never return to any previous state, and so is aperiodic: it never gets back to a previous point in its phase space, and so never repeats its path, even if it never leaves the attractor. Strange attractors were first discovered in study of the solar system, and then of the weather. They have since been found in many other places, such as signal noise and turbulence.

The nature of entropy means that we cannot predict the future of chaotic systems. Imagine a small moon orbiting a system also containing two large planets, the moon having fallen into a strange attractor, and moving aperiodically (this is known as the "three body problem"). If one takes a slice of the phase space of the system (known as a Poincaré section), the point at which the trajectory of the moon intersects that slice will jump from one place to another with no regularity. Due to the shape of the strange attractor in phase space, a small error in measurement will result in a large error in predicting where the moon will next appear on the Poincaré section. This is the case even though the system is deterministic, and the trajectory keeps passing through the slice in the moon's peregrinations around the strange attractor. So chaotic systems, of which there are many actual examples in the world, defeat accurate prediction.

2.3.1.2.3 Quantum physics

Quantum physics looks at phenomena such as radiation, space and even time as being made up of indivisible units called quanta. Quantum theory began in the course of investigations by Albert Einstein (among others) into Boltzmann's conception of entropy in terms of probability. (Smolin 2000:100)

One revolutionary feature of quantum physics is that the observer is considered to be part of the system being measured. This has the great advantage of representing what is actually the case when a scientist measures some feature of the universe, although it does create difficulties that do not exist in classical theories.

There is a sense in which the way an observer measures an everyday property such as length determines what answer is found, since all measurement takes place in a specific context of use. As Ludwig Wittgenstein remarked, "the meaning of the word "length" is learnt by learning, among other things, what it is to determine length" (1953:225). But the situation of the observer has greater consequences at the quantum level. There is an unavoidable uncertainty when measuring interrelated aspects of systems of this scale, such as the position and momentum of an electron, although the exact reason for this uncertainty is debated. The greater the accuracy in measuring one value, the lower the possible accuracy of measuring the other. The degree of uncertainty is determined by Heisenberg's uncertainty principle. The level of uncertainty is negligible for systems of everyday size, but not at the quantum scale.

To get around this uncertainty, in order to test quantum physics experimentally, the physicist Erwin Schrödinger invented the idea of the wave function. The wave function is a representation of information about a system in terms of probabilities, and bears a resemblance to phase space, although it differs in the details of its mathematics. When its position is measured, an electron could be found at any point in its phase space, although it has a higher probability of being found near its previous position.

The detective in the example above could only give a probability that the bullet-graze on a desk had happened in the course of a crime, but at least she could be sure that if she was not right, then she was wrong, in common-sense terms. At the quantum level, according to the most common interpretation of quantum physics, there is no such thing as being right or wrong about what is going on with a particle such as an electron, if both guesses are covered by the wave function, until a specific measurement is made of one of its properties. Its situation is simply “undetermined” until measured.

While we think of measurements as being made by an observer, one can also speak of the environment as “measuring” the state of a quantum system when the system comes in to contact with that environment. The wave function describing the probabilities of the system gets “lost” as it merges with the wave function of the (much larger) environment, as ripples from a stone dropped into the sea are lost among the waves. This is known as quantum decoherence. The process follows statistical rules, through the operation of entropy, and the smaller wave function is lost in the larger very quickly. This is a way of explaining why we do not observe wave functions with undetermined values in systems of everyday size. In this way quantum processes connect with the thermodynamic arrow of time, through the operation of probability in statistical mechanics. “Decoherence is caused by the interaction with the environment which in effect monitors certain observables of the system, destroying coherence between the pointer states corresponding to their eigenvalues. This leads to environment-induced superselection or einselection, a quantum process associated with selective loss of information.” (Zurek 2003: 715).

One could update a well-known question as follows: If a tree falls in the woods, and there is no-one there to witness, does quantum decoherence still apply? This is a way of looking at the uncertainty principle. The answer is: It depends how you look at it. From the point of view of measurement, there is quantum decoherence. From a point of view other than measurement, well, *is* there such a thing as a point of view other than measurement?

I will touch on the uncertainty principle again in section 2.4.5.2.7. For the time being, I will note that as far as we can tell, there are definite limits to the accuracy of measurement of very small systems. According to Heisenberg, such limits would apply even in the hypothetical case involving measuring instruments with an arbitrarily high level of accuracy. We can only speak in terms of probabilities, at the quantum scale. This constitutes another limit on our prediction of the future, since we cannot specific the state of the present with perfect accuracy.

2.3.1.2.4 Inevitability of the historical arrow of time

Is the universe deterministic or not? Is anything truly random, or is randomness just a sign of missing information? Scientists disagree, and there are good arguments on both sides. But even if the universe is deterministic, and nothing is “really” random, it seems that entropy, and the flow of information, must impose an arrow of time on any observer. A deterministic universe would provide hope of overcoming quantum uncertainty, if only in theory. But the closed nature of the universe would seem to preclude a perfect simulation of its progress being created within its boundaries, since the simulation would have to include itself and its effects, creating a paradox. And relativistic limits to the speed of information transfer, which no current scientific theory has challenged, would seem to impose practical limits on perfect simulation of even a limited area of the universe, even if obstacles such as quantum uncertainty could somehow be overcome. The prediction could not keep up with the phenomenon being simulated.

The future and the past are closed to us, in varied ways. The different reasons why the arrow of time is inevitable have much in common, however. They derive from the nature of entropy, or in other words, the probabilistic flow of change according to statistical mechanics. Here we see the first connection between entropy and our status as observers of the changing state of the universe.

Mentioning the possibility of a deterministic universe naturally leads to the topic of free will. (See for example Merali 2006.) In my view, there is no difference between seeming to have free will, and actually having free will. The distinction between "real" free will and "apparent" free will is spurious. Furthermore, the existence of randomness in the universe would seem to have little applicability to freedom. I also believe that free will has only incidental relevance to morality, and I will return to this topic in the section dealing with morality.

For the time being, we can say that within the inevitable perspective of the arrow of time, we can introduce energy into systems and thereby change their entropy flow, altering probabilities - that is, we can act. Furthermore, we cannot predict the future with perfect accuracy (which is a precondition of the arrow of time), although we certainly predict it with imperfect accuracy, thanks to the presence of probability in the flow of entropy. Without the connection between probability and entropy, consciousness and indeed observation or measurement of any kind could not exist, since everything would change arbitrarily from one moment to another, and regularity would be extremely rare. One could say that we have free will thanks to our ignorance of precisely what will happen in the future, along with our ability to guess what may happen, which together permit choice. But this ignorance would apply to an observer within a completely deterministic universe, thanks to constraints on the processing and flow of information that come along with entropy and the arrow of time.

I should note that saying the arrow of time is inevitable for observers does not imply that in fact "time is *really* frozen, it just *seems* to flow for us". We are familiar with the idea of something being frozen in time, such as a statue that has not changed for millennia. But it is potentially misleading to apply this (as a metaphor) to time as a whole, particularly if time is defined in terms of change! We should be wary of any such formulation that views things "from the point of view of the universe", since the universe does not have a point of view.

2.3.1.3 Conclusions regarding the arrow of time

Here I particularly wish to highlight the connection between the arrow of time, entropy and probability. Entropy and probability have recurred at every stage of the above discussion, which is to be expected since time (in relativity theory) is equated with change in spatial relationships, and change inevitably has an associated probability.

When the probabilities of change in the many elements of the universe are brought together through statistical mechanics, it becomes inevitable for an observer within the closed system of the universe to experience an arrow of time, as that observer receives and processes information arriving from elsewhere and from the past (those two terms being understood in terms of relativity theory).

The progress of statistical mechanics follows specific rules, which result in varied phenomena such as chaos and self-organisation. The ultimate origin of patterns is found in this specific action of statistical mechanics. It so happens that regular patterning can arise and be sustained in our universe, thanks to its expansion and its other specific properties, such as the existence of both positive and negative energy. Furthermore, this regularity follows certain rules that give rise to various “genera” of regularity. However, according to cosmologists, universes are theoretically possible that cannot support regular patterning (although they do not use the term patterning, to my knowledge).

2.3.2 Vahe Gurzadyan and negative curvature

Why should systems tend towards increased disorder? If one adds up the possible states that a closed system can move into, the ordered states will be fewer than the disordered ones, if gravity is negligible. Statistical mechanics will drive things towards disorder. But why are things set up this way?

One intriguing explanation is given by cosmologist Vahe Gurzadyan (Gurzadyan and Torres 1997, Allahverdyan and Gurzadyan 2002). There are three possible shapes for the universe, depending on the average density of its contents. It can be flat, like a sheet of paper, or closed, like a soccer ball, or open. If the universe is open, having negative curvature, then its local geometry is hyperbolic. One can visualize this in two dimensions by imagining a shape rather like a saddle. “In a universe with negative curvature, every point in space is bent up in one direction and down in another, like the mid-point of a saddle” (Gefter 2005). This topology would result in particles tending to diverge and mix, resulting in a tendency towards disorder, and thus providing a foundation for the thermodynamic arrow of time.

The scientific consensus is that the universe is flat. But Gurzadyan’s hypothesis does explain some anomalies in measurements of the cosmic microwave background radiation, as well as providing a mechanism for the particular flow of entropy we observe. The debate is not over yet.

2.4 Information

I have said above that information is not order, and entropy is not disorder. Entropy is the direction of change in a system according to probability, and is therefore associated with time.[4] For systems where gravity is a discernible factor, like a large cloud of gas in space, disorder represents less entropy than order. In this case, disorder is a relatively unlikely state, and the system will change over time to become more ordered as it contracts. (It seems our universe began in a disordered, low-entropy state.) And even for systems where gravity can be discounted, disorder is only more likely than order, without outside interference. Four gas molecules bouncing around a closed box could be found in a position delineating a square, each equidistant from two others: but other configurations are much more likely.

If entropy is not the same thing as disorder, then what is information, if indeed it is not the same thing as order? Imagine you are walking to the supermarket, hurrying to get there before it closes. As you approach, you see the lights of the supermarket extinguished. From this, you know you are too late, you know you will have no milk for your breakfast, you know the proprietor is on her way home, and many other things. You have received some information, at the speed of light, as the interruption in the flow of photons reaches your position.

Now, when a light is switched on, it is in a relatively low-entropy state, since gravity is not a factor in its operation, unlike the Sun. Energy is going into creating order, changing the flow of probability, with photons thereby being generated by the light-source. When it is turned off, disorder increases, and the system has moved towards equilibrium. You have received information through an increase in disorder.

[4] Usually, entropy refers to the tendency towards disorder in a closed system. However, I wish to define this term more broadly.

How then could information be the same thing as order?

It is better to characterise information as the measurement of change through a system, at a particular location. (Even an instantaneous measurement of a never-before-observed phenomenon involves capturing a change, as the information reaches us, though we might not know what we would have recorded a moment before. The definition of location I will leave vague until section 2.4.5.2.)

Noise (which can be relatively ordered or disordered) is therefore a form of information, although it is by definition useless information, which gets in the way of our accomplishing our purposes. Fog which prevented our telling if the supermarket lights had been extinguished would be an example of noise, although seeing that fog would provide useful information for a criminal deciding whether to rob the supermarket owner as she leaves. Useful information can also be relatively ordered or disordered. The distinction between usefulness and uselessness is made by the observer. It is quite possible for noise to have more order than the useful information it is getting in the way of.

One could view the increase in disorder of the extinguishing of the supermarket lights as order, in a broader context. It could be seen as the "zero" in a pattern of ones and zeroes, with "one" representing the lights being on. One measurement of information is in terms of the answers to yes or no questions, in terms of binary integers, usually called bits, that can have a value of one or zero. But it is clearer to say (with reference to the wider context that takes into account the possibility of the light being on) that information is being carried by a pattern, rather than saying that information and order are the same thing. Patterns naturally reside on a *spectrum* of regularity.

2.4.1 Information and patterns

It will be remembered that patterns have the possibility of regularity, or in other words, a certain degree of order, which is the same thing as compressibility. Indeed, order is simply a term used to describe this feature of patterns, and is defined in that context. (Even when we talk about law and order, we mean imposing regularity, or greater predictability, within a society.) Ordered information, in the form of relatively regular patterns, has greater potential for usefulness than disordered information.

The broadest definition of information is measurement of change propagating through a system, over time and space. Disordered change can propagate through a system, but its usefulness is relatively limited. When information is compressible, new possibilities of propagation become available. Compressing a digital photo makes it quicker and cheaper for you to send it to a friend, who can then decompress the picture to a state that is very similar to its original state on your computer. Painting a picture on canvas, then having it delivered by courier, takes more effort and is more expensive.

Of course, it should always be remembered that order is a relative term, due to its nature as compressibility. Some patterns are more compressible than others. Compressibility can result in a loss of useful information, and increase in noise, when a pattern of change is altered as it propagates. But that very loss of useful information might itself be useful for some other purpose, say, in testing an algorithm for compressing digital photos.

Living things, and many other long-lived systems, make use of regularity in patterns in both their reception and processing of information in the course of sustaining themselves, and they also use the possibility of decreasing order. (Chewing and digesting food increases disorder, while bringing chemicals to a cell increases order.) This is thanks to the relationship of order and disorder as relative terms on a spectrum of compressibility.

The great usefulness of compressibility in propagating change is one reason for the misunderstanding that information is the same thing as order. On the surface of the Earth, where the influence of gravity as a spontaneous movement towards order can usually be discounted, it is certainly possible to call information “order”, call entropy “disorder”, and set them up as enemies, for many purposes, without running into difficulty. After all, an ordered signal such as a telephone conversation is degraded by disorder as it propagates, and entropy is causing that disorder, thanks to the actual flow of probability in the system. We put in energy (using our voice, the electrical signal on the line, and perhaps even computerised error correction) to sustain order, and defeat the noise on the line. But it is much better to speak of information as propagation of change, and entropy as the flow of probability. This allows us to separate out subjective and local judgements from such descriptions.

2.4.2 Measuring information

Change and compressibility can both be measured in various ways and assigned numerical values, and this is of great use in the pursuit of theoretical and applied science. Once again we must acknowledge the implications of the undoubted need to sample a particular property at a particular point, without reference to its context, in the course of scientific investigation.

In classical information theory, one can measure the extinguishing of the supermarket lights as one bit of information, answering the question, “is the supermarket open?” But it seems that that bit, which is an absence and not a presence, can tell us a great deal besides that, such as the probability of no milk for breakfast. A stranger to the town (who does not know what the light belongs to) might not learn anything at all, except that she is no longer able to see light from that location. And what are we to say of the changes propagating through the eye, optic nerve, and brain, which result from the loss of light, and are so much more complicated than that one bit that the absence of light represents in terms of yes or no questions asked by an observer?

When talking about change, the very least we can say is “something has changed” or “something has not changed”, without any reference to how things have changed, or the context or implications of that change. This is the process of measuring information in terms of bits, and indeed the only yes or no question that one bit can answer is, “Change?” That one bit representing “something has changed” requires a much larger context if it is to result in a person realising that the supermarket has closed. We must know a great deal about that supermarket, about supermarkets in general, about those lights, and about lights in general, and many other things. That one bit results in all sorts of new propagation in the systems that observe it, these systems having been laboriously constructed through a long history of dealing with such events.

Information being closely related to change of spatial relationships, or in other words, space-time, context must always be taken into account if we are not to be misled by the process of measurement of information in numerical terms. This applies to other ways of quantifying information, such as the method of identifying information with “surprise value” and thereby connecting information content to entropy (surprise, or unpredictability, being related to disorder).

The question of how to measure information numerically is not centrally at issue in this thesis, which discusses the nature of information more broadly, and so I will not pursue this topic any further. However, I will discuss the definition of measurement at the start of chapter two.

2.4.3 Information and noise

Earlier I defined noise as irrelevant information. Absence of change is not noise. Noise is a form of change, and therefore information. The everyday usage of "information", as in "that newspaper is very informative", or "I have no information regarding his whereabouts" takes relevance for granted. If one wanted to try to give all the information one had, and said, "I don't know exactly where he is, but he doesn't have the money to get into outer space, so look on the Earth first", one would give more information, but in most cases this extra information would not be useful, any more than if one had uttered nonsense syllables instead.

What then determines relevance and irrelevance? The broadest way to put it is to say "relevance to the perpetuation of certain structures", whether helping or hindering. The position of water molecules on the surface of a snowflake is relevant to the way the snowflake grows. In a maximally ordered state, there is no change, and so no such thing as relevance. In a minimally ordered state, there is constant change, but no relevance, because structures cannot persist over time. In between the two extremes, there are states where structures can arise and persist through self-organisation. Of course, we inhabit just such a state: the surface of a planet with a protective atmosphere and a friendly star.

We cannot identify noise without identifying a purpose, even if only the metaphorical "purpose" of a snowflake forming. What is relevant information for one purpose will often be noise for another. I will return to this topic in the chapter on morality.

The difference between relevance and irrelevance is key to the difference in usage between Shannon entropy, which is measured in bits, and thermodynamic entropy, measured as heat over temperature. Data in computer memory is usually measured in terms of Shannon entropy, which only takes account of the different possibilities of arranging the data. The chip that contains the data however, has an associated thermodynamic entropy, according to the number of possible arrangements of its atoms. The two are "conceptually equivalent", but their use is determined by the scientific fields in which they turn up (Bekenstiein 2003).

The term "observer", in its broadest sense, could be defined as the persisting, relatively ordered system for which information is relevant or irrelevant. In this sense, a snowflake is an observer of its environment, although the information that is relevant to its persistence is very limited indeed. Although very many snowflake patterns are possible, these patterns arise from small variations into the input of a system of very simple rules, as a computer simulation of snowflake formation shows.

2.4.4 Information and relativity

Time is connected to information. In relativity theory, one's past is the whole four-dimensional region of space-time from which one can receive information, one's future is the whole four-dimensional region of space-time to which one can send information, and the present is the point in space-time where information arrives with one (which is obviously quite a different understanding of the present from the common sense view of "whatever is happening now, everywhere").

This places another limit to information. The highest possible speed of information transfer being the speed of light, we cannot know anything about areas further away in light years than the age of the universe, since change cannot yet have reached us from those areas. As the universe ages, the area from which we can have gained information increases in size. Statements about events beyond this horizon are neither true nor false, but undetermined (this may well bring to mind the nature of quantum indeterminacy). The mathematics for quantum theory, relativity, and cosmology must take account of the physical limitations of information transfer (Smolin 2000:30).

2.4.5 Information is physical

The constraint that the speed of light places on the transfer of information is a hint that "information is physical". This is the title of a landmark paper by physicist Rolf Landauer, in which he speculates, "Information handling is limited by the laws of physics and the number of parts available in the universe; the laws of physics are, in turn, limited by the range of information processing available" (1991).

Information can be thought of as the particular changes that occur over time in the universe, as measured from a specific location. The universe is a system (the largest possible system) with a specific physical nature, and what we identify as "the laws of physics" are generalised from, and are applied to, situations within that system. Any change that occurs necessarily happens within the physical universe, and this fact needs to be taken into account when discussing the nature of information. For example, besides being saddled with a "speed limit" (the speed of light) information is also affected by the probabilistic character of entropy. Entropy cuts off our knowledge of the past and future, ensuring that an observer of change in the universe will experience an arrow of time. Physical limits are informational limits, and physical laws are affected by the specific flow of information (we have seen that the second law of thermodynamics, for example, is only probabilistic).

Space consists of separate elements that are related, and those relationships change over time, which is the source of information. Is a relationship physical? Because relationships are always between elements of the physical universe, we must answer in the affirmative. If this answer seems counter-intuitive, it is better to fix that problem by rethinking what we mean by “physical”.

What are these undefined “elements” that permit the existence of space and time? How can the term “element” be defined so vaguely as to cover all relationships, from the relationships between quarks to the relationships between countries? What exactly can we say about these “elements” that is not expressed in terms of relationships, given that any given element will be made up of other elements, unless it is at the bottom of the chain, where we have great difficulty in seeing clearly? Why do we tend to think that these elements are physical, while the relationships between them are not, even when (say) a country is essentially defined in terms of the interrelation of its components, and by its relationship with its geographical context? Is there anything to physicality *beyond* relationships?

As for the question of the most fundamental, minimal definition of what an “element” could be, this is the subject of particle physics, and I cannot give a comprehensive answer here. That said, I will briefly address an idea that is becoming influential in information theory, cosmology and physics, for which I will use the term “the informational universe”. One might sum up this school of thought as championing the role of relationships over elements. As we continue to investigate the particles that make up matter and radiation, they seem to become more and more abstract, while the relationships that they delineate take on greater importance. This is a “vision of information as the stuff the world is made of” (Bekenstein 2003).

If one were to trace this school of thought to one founder, that person would be John Wheeler, pioneer of quantum physics and colleague of Einstein, who coined the phrase “it from bit” (the physical universe as arising from information). Much of the work in this field has been pushed along by the demands of unifying quantum physics with relativity. This battle is mostly fought in the arena of “quantum gravity” – that is, in giving a description of gravity in discrete units, or quanta, but which also fits with Einstein’s field explanation of gravity, which has had great experimental success.

The point of this section is to explain the physical character of information, and so I will address the idea of the informational universe by looking at two strictures that quantum gravity theory imposes on information: the existence of horizons, and the need for background independence. Constraints due to the universe being a closed system, and due to the physical nature of information, are related. For example, limits to representation of detail due to complexity might somehow be avoidable if the universe were not a closed system.

2.4.5.1 Background independence

The marked improvement of relativity theory over Newtonian physics is that the mathematics does not require any absolute background of points with fixed locations in space or time. This is indeed where “relativity” gets its name. Two separate events that are simultaneous for one observer will not be so for another observer moving with reference to the first. And there is no criterion for judging who is “right”.

In describing gravity in terms of quantum physics, it would seem to be an advantage if the latter were also formulated in a way that is independent of any absolute background, and where everything is therefore defined in terms of relationships. This is the position of theories of quantum gravity such as Causal Set Theory (Dowker 2003) and Loop Quantum Gravity (Smolin 2000), both of which postulate a universe made up of relationships between quantum elements at the Planck scale. Indeed, recent interpretations of Loop Quantum Gravity go so far as to say that particles may be "tangled plaits in space-time" (Castelvecchi and Jamieson 2006). This is perhaps the purest form of informational universe theory, in that it does away with the traditional idea of the physical altogether, in favour of an explanation using relationships.

Can we make my earlier definitions of entropy, time, and so on, background independent? One can picture energy, entropy, gravity, time, space and information in terms of the roles they play in constructing phase space.

- Time refers to the phenomenon of change among spatial relationships.
- Energy refers to the potential for change to propagate.
- Entropy refers to the probabilities that determine how change propagates, according to statistical mechanics.
- Gravity provides the energy to sometimes allow order to become more probable than disorder, within limited areas.
- Information refers to measurement of the specific changes that occur, at a given location.

To achieve background independence, the landscape of phase space cannot be thought of as existing apart from the relationships that it describes. Its form is generated in the process of change.

In any case, we should take from theories of the informational universe the lesson that it seems possible to describe the universe entirely in terms of relationships, with the actual elements that define those relationships being reduced to a very abstract status. Above, discussing quantitative measurement of information, I said that the only question that could be answered by a single bit was, "Change?", if that bit were truly considered in isolation from its context, apart from the previous bit, of course. (Without the previous bit, we could not even answer that minimal question.) The great informational richness of the world we observe comes from context – that is to say, from relationships. Discussion of that point must wait for the next chapter, however.

Background independence is the hallmark of a truly closed system. The closed nature of our universe has another consequence for the nature of information: imposing horizons on observers within it.

2.4.5.2 Horizons

Horizons are a consequence of the physicality of information. "Horizon" comes from the Greek for boundary or limit. The most obvious horizon is the one that is due to the curvature of the Earth, which is a limit to sight. This horizon is not too hard to overcome: one could climb a hill, which would push the whole horizon back a little, or simply move towards what one wished to see, dragging the horizon along. But not all informational horizons can be breached, although some can be pushed back. As physicist Sunny Auyang puts it, "Finitude is a human condition that cannot be obliterated by science…we can never step out of our horizon to attain God's position" (Auyang 1995:113).

2.4.5.2.1 Location

Above, I defined information as the measurement of propagation of change through a system, at a particular location. What is a location? Is it a minimally-sized point in space-time? That is the definition of the present, in relativity, but this does not seem to cover the possibility of measuring change in terms of patterns. Ultimately, however, measurement will be based on change intersecting at such minimal points, if we choose to take up a theory that reifies something termed “points”.

Speaking more broadly, location is where the measurement and processing (a pattern of measurement over time) of information takes place. The definition of “location” will vary according to the method of measurement: that is, according to the definition of the boundaries of the system being discussed. This is a subjective choice made according to the purposes of the observer of the system. “A system is not something presented to the observer, it is something to be recognized by him” (Skyttner 1996:35). A location will have an associated measurement horizon, and one could perhaps define “location” in terms of this horizon. The divergence of this definition of location from the definition in relativity theory gives a hint of difficulties in defining “the present”, which will be addressed in the chapter on consciousness.

2.4.5.2.2 Types of horizons

One could divide horizons into two categories. One type is due to the closed nature of the universe, and the fact that we are observers within that closed system. This leads to apparently immutable horizons such as the speed of light, the uncertainty principle, and the holographic bound. Lee Smolin uses the slogan, “One universe, seen by many observers, rather than many universes, seen by one mythical observer outside the universe” (Smolin 2000:48). In other words, “the universe cannot be described from the point of view of an observer who exists somehow outside of it. Instead there are many partial viewpoints, where observers may receive information from their pasts” (Smolin 2000:178).

The other type of horizon is due to entropy, that is to say, probability. The strength (as one might call it) of this type of horizon varies widely according to the probabilities of the situation. Solid objects form an effective horizon to our sight, but we can overcome this horizon by moving the objects, walking around them, etc. At the other extreme, a black hole provides an extremely strong horizon, and we can be sure we will never have detailed knowledge of what is going on within it. This second type of horizon, which could be termed an entropic horizon, arises from the actual facts of information transfer. The arrow of time is due to both closed-system horizons (the speed of light and the uncertainty principle) and entropic horizons (due to the collision between entropy and complexity).

2.4.5.2.3 The speed of light

It seems that the speed of light provides an immutably fixed horizon. Even theoretical situations involving quantum entanglement of two separated particles cannot overcome this limit (von Baeyer 203:180). We cannot receive change from areas so far away that light from there has not yet reached us; and we cannot influence such areas.

The limitations imposed by the speed of light require a system of logic with outcomes of not only truth and falsity, but indeterminacy. “Not only can an individual observer only see light from one part of the universe; which part they can see depends on where they find themselves in the history of the universe… So we must conclude that the ability to judge whether a statement is true or false depends to some extent on the relationship between the observer and the subject of the statement.” (Smolin 2000:28) One such logic, used by cosmologists and quantum theorists, is topos theory. Topos theory is capable of dealing with the existence of informational horizons, as well as allowing background independence, and so is applicable to a closed universe. “This cosmological logic is also intrinsically observer-dependent, for it acknowledges that each observer in the world sees a different part of it" (Smolin 2000:31).

Coming from the field of algebraic geometry, topos theory is related to the study of mathematical landscapes. It is a way of categorising relationships between points and their neighbourhoods. It can also be used to categorise mathematical and logical systems. Physicists Chris Isham and Jeremy Butterfield have been using topos theory in an attempt to deal with quantum uncertainty (Matthews 2007). It seems to me there is a connection between topos theory and entropy, since the former determines the ways in which points on a landscape can communicate with each other, and this in turn determines the ways (Boltzmann's "W" term) in which change can propagate.

2.4.5.2.4 The uncertainty principle

Heisenberg's uncertainty principle is formulated and understood in many different ways. One can view it is a consequence of the closed nature of our universe. "Heisenberg's insight can be understood in terms of the problem of self-reflexivity. Since observer and observed are mutually implicated in the same system, knowledge of the object is conditioned by the subject… Knowledge, therefore, is relative to the multiple perspectives from which it is constituted. This multiplicity of perspectives cannot be reduced to a single angle of vision that is true for all observers." (Taylor 2001:115) Even without the problem of entropy, quantum uncertainty would provide an immutable horizon, due to the nature of information measurement.

We cannot get exact information on both the position and momentum of a particle. The question remains whether these properties of the particle *really* both have exact values, although we cannot know both at once. Here we run into the same question that cropped up in section 2.3.1.2.3, regarding quantum decoherence. There seems little point talking about the properties one would measure if one measured something immeasurable. However, we can ask whether the universe is entirely deterministic, and it seems that although we do not know either way, it could be, at least according to physicists such as Nobel Prize winner Gerard ‘t Hooft (Merali 2006). I will give one or two reflections on determinism in the course of this thesis, although it is not strictly relevant to my conclusions.

2.4.5.2.5 Complexity

Complexity is a factor in entropic horizons. Too much complexity, together with the flow of probability, make many things resistant to measurement. (Complexity is defined in terms of the number of relationships between different elements of a given system.)

Complexity creates horizons when our measurements reach a limit with regard to the level of detail of change that they can capture. This depends on the system being used to perform the measurement, but in any case, such horizons will exist. They may come about through great disorder, which cannot be compressed. They may appear when measuring relatively ordered states that contain a very large number of relationships. Generally speaking, one can say that such horizons are made possible by the existence of nonlinear processes in our universe, in which the number of relationships jumps exponentially as the complexity of the system increases. Chaos is generated through nonlinear feedback, under certain conditions, for example. One can glimpse the power of nonlinearity to increase complexity by facing two mirrors together.

One can push against these horizons by increasing accuracy of measurement and complexity of processing, although one cannot eliminate them. Even if we did not run up against the uncertainty principle, which stops us measuring the universe in perfect detail (due to its closed nature, descriptions of the universe must stay within the universe, and so a perfect description would be paradoxical), many everyday phenomena (which are open systems) are simply too complex to be detailed, especially as they change over time.

2.4.5.2.6 Randomness

Randomness is related to horizons. Increased uncertainty indicates proximity to an informational horizon, as our measurement of the previous chain of causation reaches its limit. For example, the lottery draw on television is highly random: forty or so plastic balls are blown around by air turbulence (turbulence being chaotic in both senses of the term) for some time; then one by one they are ordered by a mechanical scoop. Even if the system were entirely deterministic, we would never be able to measure the instantaneous position of the system accurately enough to work out the backwards chain of causation. Again, when we speak of "random accidents", there is an entropic horizon very near, in the form of the massive complexity of our environment.

But everything is at least a little bit random to any observer, thanks to the inevitability of the various horizons. This minimal randomness is quickly smoothed out into the ocean of quantum decoherence. Hans von Baeyer calls this a blanket of noise, in the sense of a blanket of snow (2003:127). He goes on to say, "Without noise, the measurement or observation of a single physical quantity would require an infinite memory and an infinite amount of time – it would overload all our circuits", and noise is "the preserver of our sanity". Wittgenstein draws attention to the problems with imagining the opposite of the phrase "every rod has a length", compared with "This table has the same length as the one over there" (1953:s251). To imagine that there could be such a thing as perfect information, transcribable given infinite space and infinite time, is to imply that the universe is not a closed system, and therefore to give a misleading impression of the nature of information. Perhaps von Baeyer is just writing for effect, but his imagined picture of a world of infinite measurement is unhelpful. All the more so since, in the natural world, information measurement and processing starts at a very crude level, and only adds complexity when it has the means, motive and opportunity to do so.

It should be noted that randomness is not the same as disorder. (However, disorder will eventually lead to an informational horizon, when its complexity overwhelms measurement, and so disorder can generate randomness.) A random number generator (perhaps one making use of the uncertainty principle by using photons and a beam-splitter) might generate only ones, and no zeros, for a given period of time. That would represent order, and so randomness cannot be the same thing as disorder. But in the long run, that limited chain of order would not be part of any bigger pattern, if the generator is working properly. Degrees of randomness merely describe the uncertainty of *predictions* of the result, and so degree of randomness is in the eye of the beholder, according to the specific flow of information to that location, and the associated horizons.

2.4.5.2.7 Holographic theory

I would like to briefly mention one last form of horizon, holographic theory, which was originated by Jacob Bekenstein, and led Steven Hawking to his idea of Hawking radiation, for which he won the Nobel Prize. Holographic theory is an important component of informational universe theories.

Holographic theory started from Bekenstein’s investigations of the entropy of black holes. Lee Smolin describes the principle that Bekenstein came up with as follows. “With every horizon separating an observer from a region which is hidden from them, there is associated an entropy which measures the amount of information which is hidden behind it. This entropy is always proportional to the area of the horizon” (Smolin 2000:86). This led Louis Crane to deduce that “quantum cosmology must be a theory of the information exchanged between subsystems of the universe, rather than a theory of how the universe would look to an outside observer” (Smolin 2000:175). Holographic theory is compatible with the closed nature of the universe, including horizons and background independence.

Entropy, being related to the ways things can be arranged, can be used to measure complexity. Complexity can in turn be measured in terms of the amount of information that would be required to describe the system. Complexity also provides a limit to the patterns of information a system can generate. In terms of my own definition of information, this is expressed in terms of the difficulty of measuring the changes that the system can produce. The output of screen with four pixels, governed by a simple piece of software, is easier to measure than one with a million pixels, showing the output of a modern computer game.

It is an advantage of my definition of information in terms of change that there is naturally a correspondence between the surface area of the system and the changes it can make on its environment, given that the surface is where the system can touch its environment, and that the surface area also determines the maximum possible complexity of the system. (This latter rule is enforced through the collapse of sufficiently large systems into black holes.) The holographic theory links my definitions of entropy and information, providing the correlation between the two which is found in many different scientific domains, and is therefore to be expected if my definitions are to hold up.

Holographic theory gets its name because a flat hologram seems to us to be three-dimensional. From certain angles, a hologram can mimic the information output of (for example) a sphere, even though the hologram is flat. Holographic theory tells us that we cannot get more information on a system than can pass through the surface area of the system. The holographic horizon dispenses with one dimension, at least as far as the observer is concerned (and how real would an *unobserved* dimension be, anyway?). This has led some theorists to speculate that, in terms of scientific investigation, it may turn out not to matter if we describe our universe as having four dimensions of space and time, plus gravity, or if we describe it as having three dimensions, without gravity. The existence of gravity may be just a matter of perspective (Maldacena 2005).

2.4.6 More on measurement

Can measurement only be performed by conscious observers? Here we return to the topic of decoherence and the uncertainty principle. In this thesis, I wish to define measurement much more broadly, in a way that is consistent with my earlier definitions of entropy, time and information.

I have defined information as measurement of change at a particular location. What is changing, according to relativity theory, is spatial relationships. Patterns exist in all four dimensions of space-time. Even an "instantaneous" spatial relationship is judged as such from a particular location – time is relative. The simultaneity of events elsewhere is defined from a frame of reference. Furthermore, the measurements that establish the "instantaneous" spatial relationship are necessarily carried out in a temporal context.

Measurement requires change – the fact that systems are able to affect one another. At the most basic level, measurement means somehow specifying the effects of change, for a given system. At the quantum level, this is the sense in which decoherence results from *measurement* by the environment. Thanks to the potential for order to increase, measurement can form a chain that becomes relevant to the perpetuation of relatively ordered patterns.

Measurement comes with horizons, and we can push back at many horizons by increasing the complexity of the system through which we measure. We can use a magnifying glass, or a telescope, to capture more information and convey that information to our retina. Just shining a bright light can give us more information to work with, by introducing energy into a system and causing increased change. A camera defeats an entropic horizon (due to complexity) by recording a complex situation from a particular location, and such a recording might prove decisive in a court case to determine what has happened in the past.

Horizons such as those due to the speed of light and the uncertainty principle are directly related to the closed nature of the universe. Entropic horizons are indirectly related, but unlike the previous two types of horizon, can be "pushed back", offering "resistance" in accordance with the complexity of the system being measured. The larger and more disordered the system, the more work will be required to overcome entropic constraints. Greater detail requires greater effort to measure.

Information describes measurement of a system, in terms of the effects of change reaching a location from that system. Measurement is the specific way in which that change occurs. Measurement is the process, and information is the product. I have information that Rodney King was beaten by LAPD officers during the Watts Riots, and I got that information through video recordings. The two terms, information and measurement, are useful ways of talking about descriptions of change, but one would not make sense without the other. Information should be discussed with reference to the means by which it is transmitted: as with Marshall McLuhan, the medium (measurement) is the message (information). My memories of the Rodney King incident and my beliefs regarding it can be characterised as information, but depend on a ongoing process of measurement, in the context of the present activity of my brain. (McLuhan's emphasis on the precise form of information transmission makes sense if one recalls the physicality of information.)

In section 2.4.5.2.1, I defined processing as a pattern of measurement. To be more specific, processing is a chain of measurement across time. Information moves from one form to another, is summarised, correlated, and so forth. We speak of information persisting, from the video camera to the television station to my television, and finally to my memory, for example; but strictly speaking this is a chain of information generation, with new information arising constantly in the course of the flow of energy and time. We judge the information to be "the same" in a practical context, but change is constant.

2.5 Complexity

I have already defined complexity in terms of difficulty of compression. Other approaches might involve intricacy (detail) or irregularity. In other words, an intricate, irregular object is difficult to describe, thanks to constraints due to the physical nature of information. Irregularity is obviously a sign of disorder, and so it is difficult to precisely describe a cloud of hot gas; though it may be very easy to describe it roughly. Ordered intricacy can be found at the boundary of order and disorder. Systems that are neither strongly ordered nor strongly disordered can contain great detail within a limited space, and they may be highly ordered, yet not uniformly ordered. Such structures are often found at the boundaries between attractors.

2.5.1 Order and disorder

Order and disorder are relative terms. Given the nature of observation, it is hard to imagine absolute extremes of order or disorder for the universe as a whole. The existence of an observer to judge that either extreme had been reached would (paradoxically) imply less than optimal order or disorder, since consistent observation over time requires at least some order, to allow memory, and some disorder, in the form of change.

Judgements of order and disorder are made from a particular location. Even within a cloud of gas in space, one should be able to find regularity in the relationships of some gas molecules, through pure chance. It is difficult to make a final judgement that no possible order could exist within a given system, no matter the situation in which it were observed. We are prevented from making such final judgements by informational horizons. What seems relatively ordered to one observer may seem relatively disordered to another.

Should we speak of a highly disordered state, like a cloud of hot gas, as having a pattern? I can think of no compelling reason not to say that every system has a pattern, which is judged as relatively ordered or disordered when compared with other patterns. Of course, any system can be broken down into smaller systems, or included in larger ones, according to the situation of the observer, until horizons due to the closed nature of the universe are reached in each direction. (The ability for systems to be made up of smaller systems is sometimes called "emergence"). Order and disorder are relative terms, and so background independent, being on a continuum. Definition of the boundary between order and disorder is also a relative judgement, and will change according to the system being described. This boundary is sometimes called “the edge of chaos”, a term first used by artificial life expert Chris Langton (1990). I prefer to use the term “the edge of disorder”, since the usual usage causes confusion with chaos theory. Mathematical chaos can only occur on the edge of disorder, because of the viability of feedback in such an environment. Chaos, in the sense in which I have been using the term, is a result, not a cause, of the edge of disorder.

The edge of disorder is, obviously, not maximally disordered. The term describes an environment with a particular mix of order and disorder, and the term “the edge of order” would be equally appropriate, since order and disorder are relative terms.

Order and disorder describe relative states of patterns, describing their observed regularity from a location. A pattern should be specified together with the location from which it is observed. This implies a caveat to the general tendency of entropy to result in increased disorder. From a minority of locations, one might observe order increasing as (for example) a hot stone heats cold water, perhaps as a few molecules fall by chance into a relatively regular pattern. But from the vast majority of locations, disorder will be observed to increase. This is a component of the probability that the system is moving towards disorder.

2.5.2 Feedback

When a system changes and those changes propagate out into the environment, it is possible for a chain of changes (causation) to return to the system in some form. The probability and other features of this process are determined by the “landscape” of the environment in terms of the degree and arrangement of order and disorder. In empty space, the radiation emitted by a star, for example, is unlikely to be reflected or otherwise cause changes that make it back to the star. In contrast, activity within the star includes feedback between different regions, giving rise to regular variations in solar activity. It is much more amenable to patterning of various levels of regularity than radiation streaming into space on diverging paths. Of course, the radiation emitted by a star in a nebula of gas may cause a shock front, and so trigger the formation of new stars. This more disordered environment may well allow feedback to reach the original star, and the system as a whole evolves in accordance with complexity theory. Feedback can be observed from the galactic scale to the subatomic scale. The surface and even the crust of the Earth provide an excellent environment for feedback to occur. Our environment is in a suitable zone of order and disorder.

The nonlinearity permitted by feedback will result in complexity increasing relatively rapidly, compared to simple linear increases in the size or disorder of a system. Feedback is behind the jump from the relative simplicity of space and cosmological phenomena to the extreme complexity of living things and other systems on the surface of the Earth.

Feedback also allows a system to measure itself: for example, one can check one's reflection in a mirror. Infinite regress due to the inherent nonlinearity of self-measurement is avoided through natural restrictions due to the capacity and organisation of information processing (the physical nature of information).

An ongoing chain of repeated feedback allows measurement to be directed over time to improve the degree of relevance. It also permits error correction. These are important topics for engineers designing control systems and otherwise working with feedback. (Directed measurement is possible due to self-organisation.

Feedback between a group of systems may involve mutual adjustment, with certain changes in one system leading in a predictable, ordered way to changes elsewhere. The size of a system made up of mutually adjusting sub-systems will be restricted by physical information constraints: hence the constant competition in the semiconductor industry to find better materials for processors. Chip makers are even experimenting with biological materials in an attempt to reduce physical constraints on processing, taking advantage of the design work of Darwinian evolution.

2.5.3 Nonlinearity

Feedback can give rise to nonlinearity, as in the example of the reflection of two mirrors. This ordered intricacy is one of the main sources of complexity in the natural world. A nonlinear system such as the weather, in which feedback between small changes in temperature and cloud cover (for example) can result in a large storm, while very complex, nonetheless possesses a certain degree of order that is somewhat amenable to modelling.

Nonlinear phenomena are best modelled by nonlinear means. For example, setting up a chess set on a board displays nonlinearity, in that very many combinations of these elements are possible. However, all these combinations can be modelled using a simple notation system, that is also nonlinear.

A chess set can be set up very many ways; there are around 10^{120} possible positions. These can be represented in a branching tree structure, and chess-playing computers make use of this fact (Shannon 1950), running through all the possibilities in a linear fashion. Nonetheless, the chess set is relatively simple, compared to the Chinese game of go. The number of possible combinations in go is so high that no computer program based on searching its tree structure can play beyond the level of advanced beginner (Hendler 2006). The 361 board positions can each have three possible states, though not all positions are legal. It is impossible to calculate completely accurately the number of legal combinations, since there are so many.

Such artificial games pale in comparison with the nonlinearity of an ordinary natural system. Luckily, we do not have to process information regarding the exact state of these systems. We can use nonlinear forms of representation to approximate their relevant features, thanks to the order that is present in their intricacy. This is why humans are still able to beat computers at go, as well as manage all the more complex nonlinear situations we constantly encounter, whether driving to work or playing tennis.

The branching structure of possible moves used by programmers of chess computers is a common feature in nonlinear phenomena. From actual botanical trees to tree-like grammars found in music and language, these forms are easy to find. This tree structure is one possibility for what is called the “network topology” of the system - the way its elements are connected or separated. It is the topological similarity between, say, a map and a road system that allows us to use the former to navigate the latter: one illustrative example being the famously distorted map of the London Underground system (Gribbin 2005:97).

2.5.4 Fractals

The idea of a fractal intersects many concepts in complexity theory. Related issues include feedback, thresholds, attractors, and the relationship between mathematics and the physical world. (I will note here, however, that mathematics must be instantiated physically in some manner, due to the physical nature of information.) It touches on topics in the Relevance Category, including stability and the probability of information propagation. It is a useful topic for discussing the distinguishing features of concepts in the Signal Elements Category. One such point relevant to the topic of fractals is the ability of mathematics to describe idealised systems that are not subject to restrictions due to the physicality of information or the closed nature of the universe; another is the fractal structure of the memes that make up the Signal Elements Category.

2.5.4.1 What is a fractal?

The term “fractal” initially comes from modern geometry. The term was coined by mathematician Benoît Mandelbrot, by analogy with a shattered stone (the Latin *fractus*) (Gribbin 2005: 83). This concept led to several advances in mathematics, including new ways of defining the concept of dimension. The most precise definition of “fractal” is in terms of its dimension, but here I will be giving priority to Mandelbrot’s looser definition, “a rough or fragmented geometric shape that can be subdivided in parts, each of which is (at least approximately) a reduced-size copy of the whole” (Mandelbrot 1977:4).

2.5.4.2 Complex dynamics

Gaston Julia and Pierre Fatou are considered to be the founders of complex dynamics (Alexander 1994:1). The topic of describing directions of attraction using iteration arose in that same period of scientific advancement around the time of the invention of the steam engine (which included thermodynamics, relativity and quantum physics), the mid- to late 1800s.

Complex dynamics uses calculus, the mathematical method of describing change which flourished after 1700, and has proven useful in both science and engineering. The calculus concept of integration, to which Pierre Fatou’s doctoral supervisor Henri Lebesgue contributed, is one commonly used technique.

Complex dynamics makes use of the complex plane, which is a way of describing complex numbers. Complex numbers are so named because they are made up of two parts, in the form $a + bi$, with i being the square root of -1. Iterations using complex numbers, plotted on a plane, proved to be a useful way of describing the dynamic evolution of systems mathematically, due to the presence of this extra parameter.

After the turn of the century, Julia and Fatou introduced concepts such as Julia sets and Fatou petals. These are ways of mathematically describing the boundaries between areas between attractors, where the direction of attraction changes. A Julia set is defined by a formula, namely $f^{-1}(J(f)) = f(J(f)) = J(f)$. Iterations of the set on the complex plane result in various complicated, self-similar shapes. These represent mathematical descriptions of changes of direction at the boundary of attractors. They rather resemble ridges at the top of sand dunes, except that they are far more complicated. A grain of sand on the ridge of a dune will eventually fall down one side or the other.

Benoît Mandelbrot mapped the various possible Julia sets, distinguishing between the two topologically distinct categories for Julia sets, which are either dust-like (made up of independent points) or wholly continuous. The result was the famous Mandelbrot set, a group of complex quadratic polynomials that is mapped as a shape with infinite complexity and a Hausdorff dimension of 2 (Shishikura:1998).

2.5.4.3 Dimension

The idea of dimension is an abstract one, and not directly relevant to this thesis. Initially, dimension referred to the number of coordinates needed to define a location: a point on a line requires one number, a point on a plane requires two, a point in a space three, and a point in four-dimensional space time requires four coordinates, including one for time.

Henri Lebesgue and others extended the idea of dimension to include more complex shapes, using intersections at an arbitrary neighbourhood boundary of a point. This topological dimension was challenged by the discovery of extremely complex shapes, such as a curve made up entirely of changes in direction (the Peano curve) (Goodman 2005:18). Calculating the topological dimension of these shapes gave results that seemed intuitively wrong. For example, the Peano curve is a line, and so should have a dimension of one; but it touches every point on a plane which has a dimension of two.

To cope with this difficultly, new kinds of dimension were invented. One new way of defining dimension, often used for fractals, is the Hausdorff dimension. This defines dimension in terms of complexity. One can quantify the shape of a tree, for example, by working out how many spheres of what size would be required to capture all of the detail of its shape, and then compare the result with a different tree, using logarithms, to determine which is more complex. This allows a technical mathematical definition of fractals, namely "a set for which the Hausdorff-Besicovitch dimension strictly exceeds the topological dimension" (Mandelbrot 1977:15). However, we have no need here to pursue this definition in more detail. In this discussion we are using fractals as a convenient topic to look at attractors, feedback and complexity, and so the less precise, more limited definition from the start of this section is sufficient..

Many shapes are fractal according to the strict mathematical definition of the term. For example, one can use the Hausdorff dimension to quantify how rough a carpet is (Xu 1997). However, most interest in the study of fractals has focused on the interactions between attractors, which often results in intricate shapes with a high degree of self-similarity, and power-law characteristics. This is the root of chaos theory, and is an important topic in the study of complex dynamic behaviour.

2.5.5 Attractors

There has been some discussion of attractors already. Attractors describe the probability of evolution of a system. A practical example is a pendulum under the influence of gravity. If given a push, the pendulum will swing back and forth and eventually come to rest at the lowest point. A swinging pendulum also influenced by three magnets (extra attractors) has an overall strange attractor that can be represented by a chaotic, fractal shape (Lesmoir-Gordon & Rood 2000:49).[5]

The boundaries of attractors often provide complex chaotic or self-similar shapes, as mentioned in the above discussion of Julia sets. Perhaps the most famous strange attractor, the Lorenz or butterfly attractor, describes a system that moves from one attractor to another, chaotically. The attractor can be described deterministically in mathematical terms, but the evolution of systems having approximations of this ideal attractor in the natural world is impossible to predict, due to magnification of any errors in measurement by the complexity of the attractor (as mentioned above). The Lorenz attractor came out of meteorology, when Edward Lorenz noticed that small differences in data given to a model of atmospheric behaviour resulted in widely varying outcomes. (Gribbin 2005:56).)

Such strange attractors are found at the boundary of simpler attractors, and when sufficiently stable, persist and develop in natural systems. We can find countless examples of this feature of the particular dynamics of the boundary between order and

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[5] Although we say things like "a whirlpool is an attractor", it should perhaps be noted that the word is used to describe behaviour over time: it is an "emergent" property from a certain temporal perspective, not an object – unless it is a "mathematical object".

disorder in our universe, from weather, to fluid dynamics, to the patterns on the skins of animals and insects. I have already spoken of systems with weak feedback interaction and thresholds, in the discussion of self-organised criticalities. A "threshold" is a loose way of describing an attractor. At some point, the system moves from one state to another, in some relatively clear way – such as a rock coming loose from a mountainside.

In mathematics, attractors can be modelled using complex numbers, or more precisely, the geometry of complex algebra. Mathematics using the square root of -1 is very apt for the statistical mechanics of state transitions. Particle physics makes a lot of use of this capability, as enthusiastically described by Roger Penrose in *The Road to Reality* (2004). However, it is worth noting again that where mathematics can be completely precise, actual observation is always probabilistic. Attractors, and their boundary behaviour, as observed by us in some physical form, are too complicated to model perfectly, as well as ultimately being subject to the Uncertainty Principle. But the mathematics of complex dynamics and fractals gives us a much better understanding of how complexity in the physical world can be generated through statistical mechanics. It therefore makes an important contribution to physicalism.

While fractals in mathematics can be infinitely complex, through infinite iteration of a formula, this is obviously not the case for natural shapes that approximate those fractals, such as the leaf of a fern. Natural systems (as opposed to mathematically defined systems, which can disregard constraints such as those due to the physicality of information) do not need infinite complexity to find uses for chaotic and self-similar attractors. For example, they cover area efficiently, which is useful for trees that need to capture maximum light, or blood vessels that must reach throughout the body, or for lungs that need to maximize uptake of air in a limited space. They can be used for compressing relevant information, as in DNA, or for providing a way of randomly searching a space such as the visual field.

In many cases, taking a probabilistic approach is actually an advantage. There may be only a very few details of some phenomenon that are relevant to an observing system, and simplification in representation makes processing the relevant information easier.

2.5.5.1 Attractors and energy

A system that has come to rest in an attractor, like a pendulum in its lowest position, can be shifted out of that state by the introduction of energy. Introduce a great deal of energy, and the pendulum might end up broken on the floor – an attractor that is not inside the normal sphere of operation of the system.

Within an appropriate environment that permits complexity and stability (such as the surface of the Earth), open systems will be using energy to enter and leave attractors, and to push other systems into and out of attractors. Introduction of energy to open systems allows the flow of probability (entropy) to be managed, and so it is a valuable resource.

Acquiring more energy resources may introduce new attractors into the phase-space of a system that were previously unavailable. For example, the appearance of a new food source might allow an animal to traverse a previously-impassable mountain range. Energy allows the threshold to be crossed, and a new range of possibilities open up.

2.5.6 Modelling

Modelling can be said to require topological similarities between two different systems, with “different systems” being defined as such on some functional basis. In other words, the information flow of the two systems is comparable. For example, there is some way in which chess resembles a battle: the concepts of infantry, cavalry, fortification and leadership are replicated after a fashion. Modern videogames can model the experience of war so well that they are used to train American troops. There is an implication in the term “modelling” that the topological similarity of information propagation is being used for a purpose, or could potentially be so used. However, the precise physical instantiation need not be specified in defining the term.

Behaviour resulting from feedback across boundaries of attractors can be topologically similar across very different scales. For example Alfred Lotka developed equations in the 1920s to model a chemical reaction that proved very useful to population dynamics. The equations were arrived at independently by Vito Volterra, working in biology (Schnell et al. 2007:135), and are now known at the Lotka-Volterra equations.

2.5.6.1 Multi-scale modelling

Modelling is the heart of science (of course). The advent of computers has brought on a great leap in the complexity of scientific modelling. Besides the models of global warming that are often in the news, or the weather forecasts produced by supercomputers, computers are also used in areas such as particle physics, astrophysics, and biology. “Trees branch, fish grow scales, bacterial colonies form dendritic patterns, birds flock, tumours invade organs, grasses colonize a bare riverbank… New tools are helping us see the regulatory and adaptive properties that characterize all biological phenomena” (Schnell et al. 2007:134).

New opportunities bring new problems. These complex models are highly sensitive to the data they are given. The reliability of one model will be affected by the quality of whatever procedure is used to generate that data. This is especially the case if the model is receiving feedback, which is often the case in biology. This calls for multi-scale modelling, where important interconnected systems are modelled in context.

However, this approach is affected by the physical nature of information, because feeding back information between different complex models is extremely nonlinear. Not only are their limits due to computing speed; when a model is extremely complex, it can become too sensitive to apply generally, or very difficult for us to understand and work with.

2.6 Stability

The final category to mention in the Physical Category is stability. Indeed, this section can serve as a conclusion to the Physical Category, since stability is related to all the other topics covered, from entropy, gravity, time, and information to complexity. Open systems are noteworthy because they provide unusual stability. The energy required is ultimately derived from either gravity itself, or processes that would never have commenced were it not for matter coalescing from diffuse gas clouds into more ordered forms such as stars, thanks to gravity. It is stability that allows information to be relevant or irrelevant. Stability usually arises in a system thanks to feedback among its elements. And without stability, there would be nothing worthy of the name "system", and indeed we would not be here to name anything! Stability refers to a system staying in some relatively ordered range of states (a stable attractor) within its phase space. More properly, this is called metastability, since a maximally disordered state can also be considered stable. However, in the following discussion I use the word “stability” to refer to metastability, since this type of stability is what is of interest.[6]

As can perhaps be seen from remarks above on W. H. Zurek’s idea of Quantum Darwinism, stability is basically a matter of survival. In evolutionary theory, fitness comes from survival of a particular pattern, often involving a genotype and phenotype in their environment. Evolution is not directed from the outside (except in cases such as animal husbandry); it is simply that if a pattern *fails* to survive, it can no longer participate. This principle can be generalised beyond biology, to many persistent systems that make use of feedback. All sorts of attractors that allow persistence in a state above maximum disorder are obviously possible, and such attractors will usually rely on the boundary interactions of many component attractors.

Mathematically, stability theory uses both the algebra of complex dynamics, and thermodynamics. Thermodynamic analysis of stability in self-organising open systems is an important topic in systems ecology, as pioneered by H. T. Odum and others. Such analysis quantifies the propagation of energy in terms of the appearance of order and disorder.

Stability is statistically unlikely, in absolute terms, because it includes some measure of order. While stability can arise spontaneously in the case of very small systems, on larger scales it must be provided by an open system, which creates greater disorder than order, while taking in and giving out energy. This is a requirement of the second law of thermodynamics for our closed-system universe. For example, a brick wall must be assembled by workers. A brick wall is metastable, in that the ordered

[6] It is perhaps worth noting that metastability can have other meanings besides the sense of a system persisting in a non-equilibrium state. J.A. Scott Kelso defines metastability in terms of the ability of a system to display varying degrees of internal self-organisation at different times. “In the so-called metastable regime of the coordination dynamics, the tendency of the parts to express their own autonomy and the tendency for the parts to work together coexist all at once.” (1991:369)

pattern is persisting despite being statistically unlikely. There are more disordered combinations of the elements of the system than ordered. The creation of the relatively ordered wall required disordering in the form of food consumption, heat dissipation, etc.

We can create stable systems by directly arranging various parts so that feedback between them results in persistence over time. Most of the artificial objects that we are surrounded with have this type of stability, which we might call organised stability. (A chair is stable within a certain range of pressure, distributing weight through its structure.) However, many systems in the natural world, and many "abstract" systems that arise in the course of human interaction, achieve stability without being deliberately arranged in some form intended to be final. We might call this type of stability, which involves dynamic equilibriums, self-organising stability.

2.6.1 Organised stability

Feedback between attractors is a quick route to complexity for natural systems; often this complexity has some kind of power-law structure. However, while this is a useful technique for biological systems in particular, it is evolved or "grown" from some initial state, rather than directly organised, because of this very complexity. We see many more power-law shapes in the natural world than in artificial objects. (However, power-law shapes can be found in many more abstract areas of human activity, especially networks and systems that possess some kind of grammar.)

The feedback between silicon dioxide atoms in a glass bottle is rather simple, and a bottle can be made quickly. The wine which fills it is created using a more complicated feedback process, and we must wait for micro-organisms to perform their task of fermentation, for example. Leave the fermentation too long, and the nonlinear process will get out of control, leading to an undesirable result.

For many purposes, we cannot "grow" what we need through some iterative feedback process. Such processes have disadvantages, even though they produce results of great complexity. When such complexity is not required, or no iterative process is available, it is better simply to construct whatever is needed. Therefore we grow food (making use of self-organisation), but build houses (organised stability). Iterative processes are well suited to activities where physical constraints are not such an important factor, such as language, music and other areas that might be called "culture". While we do not grow houses, the *idea* of a house mutates as time passes.

2.6.2 Self-organised criticalities

The underlying mechanics of systems with self-organised criticalities have become much better understood over the last twenty years, thanks to the groundbreaking work of scientists including James Lovelock (2000) and Stuart Kaufmann (1993). Self-organised criticalities are found in systems consisting of many elements that can move between different attractors, with a certain degree of feedback between each element, as already mentioned in the example of a slope prone to avalanches. This results in a fairly robust form of self-organised stability, which takes the form of nonlinear interaction that obeys a power law. The Richter scale for earthquakes is one well-known example. The relationship between size and frequency of earthquakes is not linear: "Double the energy… and an earthquake becomes four times as rare" (Buchanan 2001:44).

The details of the power law found in the phase transitions in systems with threshold-bearing elements on the edge of disorder depend on the topology: that is, on the way information flows between the elements in the system. The power law emerges from just a few characteristics relating to the size of the system and the way its elements connect, and so it is easy to create simulations of real systems that are many degrees of magnitude simpler than the phenomenon they simulate, yet can nonetheless give insight into the behaviour of that system, since the statistical distribution of change will obey the same power law. The scale invariance of power law behaviour is so useful that different topological categories are called “universality classes” (Buchanan 2001:135). More broadly, the study of the specific physics of scale invariance is called “renormalisation”, a term that initially came from quantum physics (Penrose 2005:676).

Earthquakes, forests prone to fires, financial markets, avalanches, traffic flow, flocks of birds in flight, and many other natural and cultural phenomena tend to move spontaneously back towards a SOC when disturbed. When the system leaves this attractor, the complexity of the phase space means the degree of change that will propagate through the system cannot be predicted in practice (although over time its distribution will be covered by a power law). The criticality is self-organising because the system will then move back towards the attractor through internal feedback processes.

2.6.3 Self-organisation and homeostasis

A simple system with a single self-organised criticality is relatively easy to study, although its precise behaviour is impossible to predict in practice. But much of the self-organisation we come across is more complicated. It consists of a number of smaller systems (defined as such by function or topology) in nonlinear interrelation, including feedback. These subsystems have become interrelated, usually by gradual evolution, in such a way that the system as a whole displays a stability that can be highly robust and flexible.

One example of such a system is homeostasis, which has been called “the foundation of all modern physiology.”(Martini 2006:11). Homeostasis achieves dynamic equilibriums, stability that persists by responding to change. In the case of bodily homeostasis, bodily systems (such as the nervous system, the endocrine system, and other organs) send and receive information, monitoring each other and the environment. This is nonlinear: “Any adjustments made by one physiological system have direct and indirect effects on a variety of other systems.” (Martini 2006:14).

For example, the hypothalamus receives information representing temperature from receptors in the body. Given enough stimulus, the hypothalamus can produce information (propagate change) to bring more blood to the surface of the skin, and to cause sweat to cool the skin by evaporation. This helps keep body temperature in a range that is compatible with the survival of various other bodily subsystems.[7]

High temperature (too much energy) is just one threat that can push these systems out of their stable attractors. Disease and injury are two other obvious examples. Attempting to negate some change and return to equilibrium is called “negative feedback”. Another category for classifying feedback is (of course) “positive feedback”. “In positive feedback, an initial stimulus produces a response that exaggerates or enhances the change in the initial conditions, rather than opposing it.” (Martini 2006:14). In the human body, examples include blood clotting and giving birth.

Positive and negative feedback differ functionally, but in probabilistic terms they resemble each other as looping attractors, with boundaries that could be described

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[7] Human bodily homeostasis takes some time to become “fine-tuned” after birth. For example, a baby cannot maintain temperature stability so well as an adult.

using complex dynamics. For example, Alan Turing's theory of morphogenesis (described in Gribbin 2005:118) postulates "actuators" and "inhibitors" (positive and negative feedback using chemicals) to produce, among other things, the patterns found on animals and plants. This can result in fractal patterns like those from Julia set mathematics. A description of the mathematics behind patterning can be found in Rabinovich et al. 2000.

In its broadest sense, homeostasis refers to systems receiving information and responding to change, and thereby preserving stability. It needs an environment on the edge of disorder, due to the requirements of information propagation in feedback and response. Homeostasis requires an open system that is taking in and giving out energy. It either will arise through evolution (gradually falling into the pattern of attraction through statistical mechanics) or be organised directly by some living thing (a person building a thermostat, for example).

A relatively early book on the mathematics of self-organisation was *The Origins of Order: Self-Organization and Selection in Evolution* by Stuart Kaufmann (1993). Another good summary can be found in Camazine et al. 2001.

2.6.3.1 Gaia theory

It is hard to imagine genuine homeostasis on a scale greater than that of relatively compact astronomical objects of the size of planets or perhaps stars, due to the difficulty of evolving rapid and flexible feedback mechanisms through outer space (with its great distances and barren environment). At the planetary level, we can see mechanisms that seem to have achieved homeostasis over the millions of years since the Earth's atmosphere and surface settled down into their current stable state.

The term "Gaia" was coined by James Lovelock (1979) to suggest a similarity between biological homeostasis, and dynamic equilibriums maintained on the surface of the Earth between living things and processes such as weather. Gaia theory is sometimes called geophysiology or Earth systems science. Lenton and van Oijen define Gaia as "as the thermodynamically open system at the Earth's surface comprising life (the biota), atmosphere, hydrosphere (ocean, ice, freshwater), dead organic matter, soils, sediments and that part of the lithosphere (crust) that interacts with surface processes (including sedimentary rocks and rocks subject to weathering). The upper boundary of the system is at the top of the atmosphere, with outer space. The inner boundary is harder to define and can be taken to depend on the time-scale of processes under consideration." (2002:684).

One of Lovelock's most famous examples to illustrate Gaian homeostasis is "Daisyworld", which uses the mathematics of complex dynamics to model a planetary system that is able to regulate its temperature (Gribbin 2005:206). In its simplest form, the model accomplishes this by postulating feedback between populations of white and black daisies. The energy reflected and absorbed by the different daisies feeds back with their populations, and so can keep the overall temperature of the model stable.

The actual surface of our Earth is obviously much more complicated. It contains many systems of the sort that exhibit self-organised criticalities and power-law behaviour; and these attractors feed back information (change) with each other and the rest of the environment, resulting in highly complex attractor boundaries. Gaia does not have a single critical state, due to this complexity. It seems to be a self-organising system with dynamic equilibriums (Lenton and van Oijen 2002:694). Lovelock has suggested that positive feedback, such as a loop between melting icecaps and increased energy absorption, could push the surface of the Earth out of its homeostatic attractor, with unfortunate consequences (2006). However, it is difficult to predict such problems precisely, due to the complexity of the attractors involved.

2.6.4 Stability and chaos

Some feedback patterns move a system towards a steady state, while others may result in disorder increasing until the system cannot function, and disappears. Still others may result in moving between various equilibriums, whether in response to change or simply as an intrinsic feature of the dynamics of the feedback pattern.

As already mentioned, chaotic attractors can result from particular arrangements of feedback. Biologist Robert May discovered one of the early examples of chaotic transitions between equilibriums in his study of the mathematics of population, which of course uses iteration (1976). In the mathematical model, a population increases to the limit of the environment to support it, then drops back. After a certain period depending on the reproductive success of the population, it begins to climb again. Some values for the parameters of the model end in a fixed population, if the limits of the environment are not reached; others result in a steady oscillation between a limited number of population levels. But other values will result in the system moving between equilibriums in a chaotic fashion, following a strange attractor. A graph showing whether particular growth parameters lead to a regular or chaotic sequence of population levels, known as a bifurcation diagram or Feigenbaum diagram, displays fractal self-similarity of infinite complexity (Gribbin 2005:76). This mathematical discovery has provided a neat example of a chaotic attractor within the application of a simple iteration.

2.6.5 Conclusion

The discussion of stability brings to an end my explanation of the Physical

Category. I hope to have given sufficient explanation of the physical processes that allow stability to appear. Once we have stability, we have a means for distinguishing between relevant and irrelevant information, and so can proceed to the next category, the Relevance Category. As stated in the introduction to this thesis, my intention has been to provide a physical basis for questions of relevance, and so open up the possibility of moving on to moral philosophy and philosophy of consciousness.

3. The Relevance Category

> It has been pointed out by Boltzmann that the fundamental object of contention in the life-struggle, in the evolution of the organic world, is available energy. In accord with this observation is the principle that, in the struggle for existence, the advantage must go to those organisms whose energy-capturing devices are most efficient in directing available energy into channels favourable to the preservation of the species.
>
> Alfred J. Lotka (1922:147)

It is fitting that Boltzmann, who defined entropy in terms of probability, should have pointed out the importance of energy to open systems. Energy gives open systems control over probability, allowing for persistent stability, and for a system to move itself (or other systems present in the environment) from one attractor to another. This may involve increasing order (building a brick wall) or increasing disorder (eating lunch). As Lotka says above, the motivating principle is survival (persistence).

The energy that permits the existence of open systems ultimately requires the organising influence of gravity, as discussed above. Open systems themselves come about in the process of statistical mechanics, thanks to feedback. Systems can eventually fall into probabilistic attractors whereby interaction between elements of a system results in the limited appearance of order, given the right conditions, and enough time. One thing that is helpful to this process is the great intricacy that can arise from nonlinear feedback, thanks to the complexity of behaviour at attractor boundaries.

It seems possible that the statistical interaction of the elements that make up our closed-system universe goes all the way down to the quantum level, according to Zurek's idea of Quantum Darwinism, already mentioned. However, the surface of the Earth is particularly apt for the evolution of open systems, consisting as it does of varied elements (mostly formed by earlier stellar processes) and a vast variety of kinds of molecules, all in steady but mild gravity, with plentiful solar and geothermal energy, protected by an atmosphere that facilitates feedback between air, water and land (all three of which are made up of interconnected elements that can develop self-organised criticalities). These conditions allow for feedback patterns over distances that are relatively short, through channels that permit a high degree of intricacy and order.

The extreme complexity of the flow of probability on the surface of the Earth gives rise to new patterns, described by areas of science such as biological evolution, and game theory. While one may speak of say, a radiation shock front being "relevant" to the formation of a star, since it contributes to the persistence of a metastable system, it is on the surface of the Earth that relevance really gets going.

The Relevance Category is a subset of the Physical Category. There is always some physical instantiation for even the most abstract formal scheme, even if the scheme itself does not attempt to model limits such at those from the physicality of information. However, the Relevance Category is distinguishable as a subset of the Physical Category due to topological features, which allow new "ways of talking". These topological features ultimately result from nonlinear interaction on the edge of disorder.

The issue of consciousness becomes a problem at this point. Does it make sense to say consciousness is physical?

3.1 Systems theory: energy versus entropy

Systems theory tends to examine open systems from the perspective of energy. H. T. Odum developed a system for diagramming energy flow called “Energy Systems Language” (Odum 1994). He also introduced terms such as “emergy”, or embodied energy, and empower, which is the flow rate of emergy (1995).

This focus on energy is due to the influence on systems theory of energetics. Energetics is another discipline coming from the period after the mid-1800s, when calculus met the steam engine, which we should perhaps call “the thermodynamic revolution”! It is one way of distinguishing between useful and useless energy. Energetics could be considered a common ancestor of systems theory and information theory (Angrist & Hapler 1967:28). Lotka introduced ideas from evolution into energetics (1922).

Energetics focuses on energy, as the name implies. There is even a “maximum power principle”, again coined by Odum, which he states as: “During self organization, system designs develop and prevail that maximize power intake, energy transformation, and those uses that reinforce production and efficiency.” (Odum 1995:311)

I think that for philosophy it is much better to change the focus from maximising energy to *managing entropy* (the flow of probability) instead. It is certainly true that, for an open system, intervening in the flow of probability requires intake and output of energy. Once we have grasped that point, however, I think the most interesting topic for philosophy is the properties of the tasks (alterations in the flow of probability) that are thereby accomplished. Accordingly I will introduce the term “entropy management” in this chapter.

3.2 Relevance and stability

The Relevance Category is concerned with survival. In biology, survival requires the feedback process known as genetic reproduction. One of the great insights of Darwin was that this process is "blind", using trial and error rather than foresight, as explained by Richard Dawkins (1986), etc. This carries over into survival in general, not just survival as biological reproduction. Time passes, and statistical mechanics plays out. Some systems can be said to persist over time. Failure to survive means that the system has disappeared. If we ask why we observe some systems and not others, one answer is simply that those are the systems that have appeared, but not yet disappeared, in statistical mechanical progress of the universe over time.

Survival implies metastability: attractors other than maximal disorder. (Nothing could "survive" in maximal disorder since by definition the term implies constant change.) The ultimate physical basis for relevance is the possibility of statistical mechanics on the edge of disorder. This is the broadest sense of relevance: information that influences metastability. Without metastability, there could be no basis for distinguishing between relevant and irrelevant information. There would be nothing but constant change.

Open systems allow for a more limited definition of relevance. They are interested in some kinds of metastability, and not others. The existence of an open system implies entropy management, since such systems are too ordered to persist due to random chance. Morality involves relevance to entropy management; but this limited type of relevance is contingent upon the broader phenomenon of metastability. I will return to this topic in section 3.4.3.

An open system need not refer to a biological organism, of course. But here I am particularly interested in self-organising open systems, because of their complexity. The development of a certain level of complexity is necessary for the term "morality" to be meaningfully applied. (Moral questions would not arise in an empty universe!)

3.3 Entropy management

It is a requirement of survival of open systems that they actively manage probability. The degree of order in an open system implies an attractor (or dynamic system of attractors, more precisely) that is difficult to reach. An open system must inhabit the edge of disorder, and so makes use of both order and disorder (order requiring the creation of disorder somehow, in any case). Movement out of the attractor that permits survival is all too easy, but practically speaking, this is an inevitable consequence of the flexible environment required for open systems to appear in the first place.

There are innumerable possible illustrations of these principles, since there are so many self-organising open systems. For example, a monkey provides the energy and chemicals to keep bodily homeostasis going by eating fruit, maintaining order in its body while disordering the fruit (and the fruit tree). It will fight to protect itself by inflicting wounds on a rival or predator. One may analyse any activity performed by an open system in terms of its effects on order and disorder (probability).

We may see the need for entropy management as unfortunate. Many of the actions we perform to influence probability can seem pointless, a waste of time. But we could never eliminate entropy management altogether. We might wish to become rich, so as to avoid the more mundane aspects of entropy management. But no matter what resources we acquire, we will still have some purposes, and engage in action to bring them about. Purpose must always be somehow related to entropy management.

Not only must an open system engage in entropy management to survive, due to the need to preserve its ordered state, but entropy management is the *raison d'être* for open systems. Even the infinitely powerful gods postulated by theologians are described as having desires that they act to accomplish. The alternative case is unimaginable: one cannot even say "all desires would be achieved instantaneously", because there would be no reason for desires ever to have formed. One can imagine asking a genie to grant a wish that one would never want for anything again; and accordingly being struck dead, that being the only possible state compatible with such a request.

3.3.1 Entropy management and time

One writer begins an explanation of research into the arrow of time by Vahe Gurzadyan in the following way: "You wake up one morning and head into your kitchen, where you get the distinct feeling that something strange is going on. A swirl of milk separates itself from your coffee, which seems to be growing hotter by the minute. Scrambled eggs are unscrambling and leaping out of the pan… Apparently, you conclude, time is flowing in reverse." (Gefter 1995).

But there is something very odd about this thought experiment. How could I, the observer, be separated from this reversal of statistical mechanics? How could information make its way to me? And if the arrow of time had reversed for me also, then I would not notice anything unusual. For the observer, time is revealed in the flow of probability. The requirement for open systems to engage in entropy management fixes the arrow of time for such observers.

Allahverdyan and Gurzadyan propose a "curvature anthropic principle", which states that conscious life could only evolve in a universe with negative curvature, which, according to the authors, gives a natural tendency towards disorder (2002). Regardless of whether their hypotheses regarding the curvature of space are borne out, I do believe that one could formulate an "entropy anthropic principle". That is, our presence as observers requires time asymmetry, probability, and metastability (thanks to a general tendency towards disorder which can be overcome).[8]

We should not view the arrow of time, horizons to information due to complexity or other factors, the probabilistic nature of observation within a closed system, and other such phenomena as *unfortunate* limitations. Rather, they are the foundation of observation: they make observation possible; without them, there would be no *need* for *any* activities, including the receipt and processing of information. One might say that "everything would happen at once", without these horizons and limitations; but this would be an unusual sense of the word "happen", which implies development in time. Time, and the world, exist for us because of the need for entropy management.

3.3.2 Entropy management and morality

Being so closely linked to purpose, and having a clear basis in the eminently physical realm of probability, entropy management would seem a promising candidate as the "currency" of a physicalist Utilitarian-type morality. By currency, I mean "utility" or whatever else may be stated as being worth maximizing or minimizing in a Utilitarian theory of morality – such as pain and pleasure, for example, in Jeremy Bentham's theory (1789). Entropy management would seem to fit well with our moral intuitions, which I would go so far as to say exist in all human societies, and even perhaps in some ape societies, regarding aiding or harming others.[9]

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[8] I suppose it is possible to imagine a universe where order was somehow more likely than disorder, and the inhabitants had to focus on keeping order under control, rather than disorder. If so, this would still be a form of entropy management.

[9] A believer in "fate" might propose absolute indifference to benefit or harm, hypothetically at least. A

Of course, things are not so simple as plugging entropy management into Bentham's Utilitarianism. We have to take various questions into account, and look for answers that are compatible with constraints due to the closed nature of the universe, the physicality of information, etc. Three important questions for any attempt to construct a theory of morality that includes entropy management are:

Who are the players? Entropy management can be performed by insects and computers, but we don't normally think of these open systems as having status in the moral game.

How do we balance aid and harm? In other words, how much weight should be assigned to particular purposes in the ongoing calculation?

How can we be sure we are right? This requires some theory of truth.

Such a theory should also be able to cope with the traditional question in Western moral philosophy of the nature of free will and its relationship to moral responsibility. The rest of this chapter will address these questions.

If a theory of morality is going to be compatible with the physical nature of information, it has to accept some constraints to knowledge, and find ways to work around them. We have limited knowledge about the future, limited knowledge about others' experience, and indeed our most detailed knowledge of the simplest systems eventually must become probabilistic, at the quantum level if not before. There must even be a limit to self-knowledge, because such recursion cannot go on forever.

I believe the problem of balancing purposes, knowing others' experience, and responsibility can be solved by game theory. The question of "who can play" is in the domain of neuroscience and philosophy of mind.

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thoroughgoing proponent of such a belief would soon die of thirst, however.

3.4 Game theory

Game theory provides a way of quantifying purpose in a situation of limited information, and therefore is very useful as part of a theory of morality that is compatible with informational horizons.

According to Dimand & Dimand (1996), game theory is descended from economics (Cournot 1838), political theory (Dodgson 1884), military tactics (Lanchester 1916), and the mathematical analysis of games such as card games (Borel 1921). Game theory is usually said to have been founded by John von Neumann and Oskar Morgenstern. "Von Neumann and Morgenstern's *Theory of Games and Economic Behavior* (1944) made great advances in the analysis of strategic games and in the axiomatization of measurable utility theory and drew the attention of economists and other social scientists to these subjects." (Dimand & Dimand 1996:142). Von Neumann, colleague of Albert Einstein, Kurt Gödel and Alan Turing, is said to have proposed a nuclear strike on the Soviet Union before it could develop nuclear weapons (Macrae 1992), which may be an example of the dangers of relying too much on theory.

Iteration plays an important role in game theory. It is an exploration of phase space probabilities for competing systems with limited knowledge of each other. It examines equilibriums that become established over time as the strategies employed by these systems undergo nonlinear feedback through information propagation. Game theory is a modelling technique that can be attempted anywhere that open systems are set up in competition this way. One notable application is its incorporation into the biological theory of evolution, by scholars such as John Maynard Smith (1982). Its application in evolution extends game theory to simple trial and error situations where foresight is not taken into account. However, evolution in the algorithmic sense is still found in models including anticipation of the behaviour of competing systems, as the system as a whole drifts around dynamic equilibriums as iterations progress.

The best-known example from game theory is the prisoner's dilemma (Dresher 1961). Two prisoners, held separately, are offered rewards for differing levels of cooperation; with the proviso that their reward also depends on the action of the other prisoner, of whose choice they cannot be sure. Iterating a mathematical representation of this game results in equilibriums that shift over time (Axelrod 1984). In this example, each player is only concerned with its own payoff; adding further layers of concern for the purposes of other systems, and the mathematics becomes very complicated.

We are adept at judging game-theoretic situations (and indeed we seem to gain pleasure from this activity, given the popularity of soap operas and television programs such as "Big Brother" and "Survivor"). For example, mathematical questions topologically replicated as social questions are sometimes easier to solve (Cosmides 1989). There is some evidence that language and other aspects of consciousness evolved as a result of their evolutionary advantage in managing large groups (Dunbar 1996). Perhaps it was the need to cope with complicated game-theory calculations that originally kick-started our rather amazing ability to deal "intuitively" with nonlinear technological and cultural systems, the precise details of the organisation of which often escape us.

3.4.1 What is a game?

Wittgenstein talks about defining games at the start of *Philosophical Investigations*. "What is common to them all? – Don't say: 'There *must* be something common, or they would not be called 'games'' – but *look and see* whether there is anything common to all. – For if you look at them you will not see something that is common to *all*, but similarities, relationships, and a whole series of them at that." (§66). However, it is still possible to talk about what sorts of things the word "game" refers to: "And the result of this examination is: we see a complicated network of similarities overlapping and criss-crossing: sometimes overall similarities, sometimes similarities of detail" (ibid.). Wittgenstein is using topological terms; I will look at the topological characteristics of signs like words in the next chapter. For the time being, we can still look for similarities in things called "games". Wittgenstein discusses games from chess to patience to ring-a-ring-a-roses.

In my view, one similarity between games is lack of full knowledge and full control. Probability is involved somewhere, either in making a choice or perhaps just observing the flow of statistical mechanics. A baby could be amused (for a short while) by a game which played out exactly the same way each time; but for a baby, such an example of exact regularity would be a novel experience.

Wittgenstein broadens the usual definition of games to include "language games" that include speech and other related actions. The term "is meant to bring into prominence the fact that the speaking of language is part of an activity, or of a form of life." (§27). Similarly, the hunt for a criminal might be called "a game of cat and mouse". When people liken business, war or love to a game, usually they are emphasising the use of strategy and the presence of competitors (although perhaps also making light of outcomes). In game theory also, lack of perfect knowledge, competition, and strategic decision-making are stressed.

Following such usage, I think there is a sense in which one can say that morality is a game. This usage should not be taken as downplaying the importance of morality, of course. Rather, it should be seen as emphasising the importance to morality of informational horizons, decisions based on probabilities, and competition and negotiation in the course of entropy management. This underscores the importance of concepts shared by morality and games, such as aid and harm, trust, cooperation, and deterrence; as well as the practical, material character of moral actions. ("Talk is cheap", but most entropy management is expensive.) Morality would be a non-zero-sum game, since many moral outcomes involve gains for all parties.

3.4.2 "The moral calculus"

It is possible to postulate a mathematical Utilitarianism, where purposes are assigned numerical values on criteria of entropy management or some other basis. For example, loss of an article of clothing could be given a value of one, and death could be given a value of 100; and this would indicate that one should use one's shirt as a tourniquet if that would prevent someone's death, which fits with our moral intuition. This would result in what might be called a "moral calculus", perhaps with the results of the outcomes of various events plotted upon some landscape, with higher points representing better outcomes. This would be modified in some way according to the status of the participants, with humans getting more points than insects.

However, an understanding of limits to information due to complexity, etc., means that we cannot for a moment take this "calculus" to have some kind of physically-instantiated existence in its own right. Rather like a fractal, we can take a look at some isolated area of the theoretical map of outcomes, if calculated approximately using arbitrary values, and plotted in some way. But the "moral calculus" itself does not exist, any more than the infinitely complex Mandelbrot set could be completely instantiated in our finite universe. Rather, it is a formal scheme devised to a certain purpose, to aid practical action. It uses simple elements in combination to explore a nonlinear space.

We can compare actual outcomes with imagined alternatives, and judge them better or worse. In such a case we presume perfect information, with regard both to actual and imagined events. This assumption of perfect information is a consequence of modelling; but we should not confuse the model with that which is modelled. It is much less complex, being a formal representation indicating assumed general probabilities.

This point is often ignored in moral philosophy, especially when it comes to the use of hypothetical examples, which are naturally very common in this (relatively) practical field. Hypothetical examples can be useful to check a theory for contradictions, using our well-honed ability to analyse the logic of human interaction, mentioned in the previous section. However, the selection of how much detail to put into any hypothetical example is an extremely loaded one. One ends up saying, "Would it be moral to assassinate Hitler, *all other things being equal?*", but of course things never are. Founding a moral theory on such examples is a perilous business, and *prima facie* indicates a lack of understanding of the difference between a theory that can presume perfect knowledge, and the reality to which the theory is applied.

Game theory, which assumes limited knowledge, provides a way to avoid this problem while still permitting some form of quantification of morality. Balancing of different purposes takes the form of actual negotiation between players. Evidence of some kind, even if only very broadly probabilistic, is required in this process. There is no "eye of God" instantiation of all possible outcomes of the situation; and even knowledge of the physical situation quickly hits informational horizons, especially those due to time and complexity. So in balancing, for example, our own interests with those of an animal, we can only do our best to understand how much the animal's purposes “matter” to it, continually reviewing what seems to us as evidence, and not assume that such a question can ever be answered to an infinite degree of precision in a “moral calculus”.

The same principles apply to questions involving presumed *future* purposes, which might arise in discussion of abortion or environmental problems, or ethical questions regarding thwarting the immediate desires of children or drug addicts. Game theory provides a practical way of balancing interests in such cases of limited information. As long as evidence can be provided that such purposes may arise, they can be taken into account.

It would seem to be a logical conclusion of this kind of Utilitarianism that it is better for players in this moral game (human beings, for instance) to exist than to not exist, if too much pressure on resources required for entropy management does not result: and this would fit with our moral intuition that it is better for humanity to have flourished over the millennia than to have remained as a few thousand individuals living hand-to-mouth on the African grasslands.

3.4.3 Responsibility

The topic of free will and moral responsibility of course has a venerable tradition in Western philosophy. But the question of whether something is done freely would not be nearly so interesting to philosophers except for the question of determinism. That said, one point worth noting, which does not touch on determinism, is Thomas Hobbes’ observation that “free will” does not mean the will has freedom, but that a person has freedom (1651:146).

What sort of position should we take on free will and responsibility, if we take into account limits to information? It seems that the universe may be deterministic, though we may never receive proof of that. One question is whether we should care at all if the universe is deterministic or not. On the one hand, if consequences do not proceed deterministically from actions, then it is hard to see what use the concept of responsibility could be. On the other, if actions are fully determined by the physical state prior to where we define the "action", that would also seem to create difficulties for the idea of responsibility.

How did the question of responsibility arise in the first place? Responsibility is needed to guide iteration, in game theory. If I do not somehow give you feedback on your actions, you will not take my interests into account. No matter what philosophers or scientists say about the doubtfulness of the idea of free will in a deterministic universe, it is unlikely that we will shut down the justice system as a result. The obvious benefits to entropy management of holding people responsible are just too great, being one element of creating the trust needed for ongoing cooperation.

It is quite natural for a desire for justice to be one of our deepest instincts, given our evolutionary history in large groups of cooperating individuals. However, punishment or deliberate withholding of aid (which I will treat as similar) for reasons other than balancing entropy management is not moral for the Utilitarianism I am sketching in this chapter. Possible moral reasons for punishment include influencing future behaviour, fulfilling people's wishes, or reducing potential future harm. If no similar entropy management considerations apply, it is not moral to punish. This is quite a different outcome from many religious moralities, perhaps because the latter are partly codifications of our simple instinct to enforce responsibility (which instinct is often morally justified, but not always).

Putting responsibility in the context of game theory gets rid of any incompatibility between determinism and free will. In this view, free will becomes a consequence of informational horizons that accompany observation in a closed-system universe. Insofar as observation by an open system permits entropy management, with limits to information about what is happening elsewhere and elsewhen, free will is inevitable. There is nothing intrinsically moral about punishing past actions; only present desires and future probabilities need be considered. Responsibility is a rule in the morality game, rather than something of intrinsic moral worth. The goal of this form of Utilitarianism does not go beyond balancing entropy management.

Speaking of free will as arising from the nature of observation by open systems, within informational horizons, does not mean that the term itself is useless. The consequence of this type of concept of free will is to get rid of philosophical conundrums relating to determinism. However, statements such as "free will does not exist" become harder to understand. Free will is not a thing that could *exist* or *not exist*, in this interpretation. We cannot arrive at a perspective that discounts informational horizons, because these are inevitable outside of formal theory.

Raymond Smullyan captured the difficultly of an observer being able to tell whether free will "exists" in his essay "Is God a Taoist?" (Hofstadter and Dennett 1982). On a related note, one might even note similarities between this question and the issue of the difference between *tiān* (the divinely ordained order of things) and *rén* (human purposes) in classical Chinese philosophy, discussed in Graham 1989. As Zhuangzi said around 300 BCE, "Knowing depends on something with which it has to be plumb; the trouble is that what it depends on is never fixed. How do I know that the doer I call 'Heaven" [*tiān*] is not the man [*rén*])? How do I know that the doer I call the 'man' is not Heaven?" (Graham 1981:84)

One possible interpretation of the problems caused by determinism is by analogy to Bennett and Hacker's idea of the "mereological fallacy" (2003), which will come up in its proper context in the discussion on consciousness below. This is a fallacy of applying to parts descriptions which only apply to the whole. An example would be Hobbes' remark that freedom belongs to a person, not to the will: purposes do not have freedom; rather, we have freedom to choose our purposes. Bennett and Hacker use the term to criticise philosophers of mind who speak of the *brain* seeing, for example, rather than the person. Likewise, one might say that freedom belongs to the observer, not to the process of statistical mechanics that plays out in the course of information propagation. A similar point might be regarding arguments against free will from neurological experiments such as those of Benjamin Libet (2004:123).

3.4.4 Objectivity

If information is always measured at a location, the traditional concept of objectivity is called into question. What is the difference between objectivity and subjectivity, in a closed system universe where any observer must experience informational horizons? This is obviously a difficult topic, and here I can only indicate the direction I believe is most fruitful.

One situation in which the question of objectivity arises is when two observers must agree on some observation. Every observer has a location, and each will see an object from different angles, and receive information at different times according to factors such as distance and relative movement. Another example where the concept of objectivity will arise is when a single observer finds, over time, that observations cannot be relied upon: for example, the mirage of water in the desert caused by refraction of light. These are *functional* situations, and in my view, objectivity depends on functionality. Statements or beliefs are true for some observer, or group of observers, in a particular historical and temporal context, in the course of entropy management. (As Wittgenstein says, “Could someone have a feeling of ardent love or hope for the space of one second – *no matter what* preceded or followed this second? – What is happening now has significance – in these surroundings. The surroundings give it its importance.” (1953:§583).) Truth is a matter of reliability, for a particular observer.

Objective truth requires accumulation and comparison of evidence by an observer or observers. With regard to the truth of some proposition, two observers must first agree on prior definitions, and other “rules”. Even a single observer realising that an oasis is a mirage must understand what those terms mean, either linguistically or purely in terms of entropy management. With regard to the truth value of beliefs, which might never be put into language (such as a belief that a chair will support my weight), Wittgenstein gives a pithy answer: “The feeling of confidence. How is this manifested in behaviour? An ‘inner process’ stands in need of outward criteria. An expectation is embedded in a situation, from which it arises.” (1953:§579-581).

It is not useful to search for a sense of objective truth by means of which something could “really” be true for all observers at all times. This is ruled out by the nature of information in accordance with the theory of relativity, the uncertainty principle, etc. It is even more misleading to speak of something being true regardless of observation. What is this “something” that is true, in such case? What example of such a truth could be given, free from all observational context? We need not always limit the term “observer” to open systems: one of W. H. Zurek’s slogans is “the environment as witness” (Ollivier, Poulin & Zurek 2004). However, information implies measurement of some kind.

This approach to truth means that statements regarding morality can be objective: all judgements of truth must be made in a particular context, and despite unavoidable limits to information, after all. It is possible to agree on criteria for moral judgements, just as it is possible to agree on criteria for saying whether the Statue of Liberty is in New York. However, that is not to say it will always be as easy to come to some common functional approach. The question of the location of the Statue of Liberty might be muddied by the presence of a smaller version in Paris; but moral questions are usually very complex, and involve judgements on the strength of others' desires, to cite one factor that is particularly affected by informational constraints. If we say that moral judgements are "not as objective", that is shorthand for the difficulty of agreeing on a reliable functional context that works for the observers involved.

3.4.5 Policy

This form of morality – a Utiltarianism based on entropy management that takes constraints on information into account – is not prone to producing statements such as "abortion is wrong". Nothing is absolutely right or wrong: right and wrong come about through the specific purposes of the actual players in the game, over time. All consequences for all players (present and future) are relevant, and the resulting situation is usually far too complex to be reduced to such simple maxims.

It is possible to talk in general terms about balancing "strength" of desires, in terms of entropy management. For example, one person's desire to keep living ought to be stronger than another's desire for a pair of sneakers, and so it is wrong for the latter to kill the former for that entropy-management purpose. However, here we are back in the realm of simplified hypothetical examples, which tends to lead to digression and confusion.

The main focus of this form of morality, which uses game theory as a way of dealing with limits to information, should be on general mechanisms that allow cooperation and balancing of desires over the long term. This gives this morality a very practical bent, focussing on aid, trust, negotiation, and other principles from game theory. This allows for natural processes such as discounting (in the economic sense) future interests to the extent that they cannot be guaranteed, for example. Game theory also provides a way of explaining why and how interests should be taken into account that are rather separated (in time or otherwise) from whatever matter is being discussed. It can provide a method of quantifying "social fabric" arguments.

The strategies that this form of morality will tend to endorse are those that encourage transparency, trust, negotiation and fair dealing. This is because it can be shown using game theory that cooperation and trust tend to result in greater acquisition and exploitation of the resources that are required for entropy management. Furthermore, mechanisms to improve transparency and otherwise make relevant information available are needed to gather the evidence required for reliable balancing of purposes. Another principle of such a morality will be to promote understanding of how systems work, so that these mechanisms can be used effectively.

The systemic structure of such strategies will promote flexibility, efficient and detailed collection of information, and feedback mechanisms for correcting errors. Specific examples would include representative government, private property, regulated markets, progressive taxation, freedom of speech, a politically-independent judiciary and police force, and so on.

Of course, these are the features of democratic government since the Enlightenment, which, it seems obvious to me, is a more moral way to organise society than totalitarianism, precisely because of how well it is able to balance the purposes of its citizens using effective game-theoretic strategies. Power is still very unevenly distributed in such societies (not to mention between these states and less fortunate ones), which of course distorts the game. Not only are resources needed for entropy management distributed less than optimally, but access to relevant information required to act effectively is also unequal. However, history has certainly shown that attempting to enforce order on a society by totalitarian means is not a preferable way to solve the problem of inequality of resources and information needed for entropy management. Rather, we should recognise the complexity of the systems that make up our societies, and attempt to order them through self-organisation, including game theory.[10]

One possible consequence that could be taken from this form of morality is that it is wrong to harm the interests of legitimate players in an attempt to act on behalf of gods, spirits, or other entities whose existence seems uncertain. In particular, when we are asked to take into account the interests of an entity for which there is little or contradictory evidence, to the detriment of the interests of others whose existence is not in doubt; and furthermore, the interests of this alleged entity happen to coincide with the interests of the person making the unsupported claim, then we certainly should be very cautious that we do not act immorally.

The same point would apply to any attempt to attribute intrinsic moral status to the nation state, for example: we have no evidence that a state (as opposed to its rulers or citizens) can have desires. And of course, assignation of moral weight on grounds unrelated to entropy management, such as mere possession of a certain skin colour or gender, are also ruled out.

[10] However, we should be aware that such nonlinear systems must be “grown” slowly, because of the need for mutual trust to be established among a large number of players. Democratic institutions cannot be imposed by *fiat*, if such trust is missing.

3.4.6 Conclusion

This sketch of a possible approach to morality based on entropy management has avoided one rather glaring question. Given that relevance relates to the survival or otherwise of metastable structures, to which structures should we give priority, and why? To some extent, game theory provides a way around this question. We simply *recognise* the status of other players in the morality game: and so the discussion above has been possible, dealing with broad issues and simple examples such as murdering a human being for the sake of a pair of sneakers. The question of whether someone should be considered as a moral agent or not is like any other question of objective truth: one accumulates and compares evidence until what is deemed an acceptable level of reliability is reached, according to the situation. Settling any question beyond all doubt, for all observers and for all time is not possible, thanks to informational limits.

It is true that there will be borderline cases where we are unsure how much weight to ascribe to the purposes of some candidate for moral status: questions involving animals, the intellectually handicapped, or even artificial intelligences. In such situations we will look for theoretical guidance. Generally, however, we have not needed absolute agreement on a formal theory of morality in order to develop practical methods for balancing entropy management: especially when the presumed interests of supernatural entities are not considered. For example, the typical criminal justice system will weigh immoral actions on a practical scale that seems to conform to an entropy-management standard. Murder, which is a disruption of the entire open system to the point where it fails completely, is ranked at or near the top. At the other end of the scale, we punish crimes where no actual harm may have been done, because of a recognition of the need for consistency in maintaining the certainty required for cooperation – a game-theoretic principle.

This is one of the most difficult topics found in philosophy, since it lies at the intersection of morality and philosophy of mind. The rest of this chapter will look at the question of where moral status comes from. However, I must introduce one more concept first, for the sake of this discussion, and also the discussion in the final chapter of this thesis: the term “meme”.

Although the previous discussion on the possible connection between order and morality, and the performance of morality under conditions of limited information, has necessarily been rather brief, I hope that it has provided some food for further thought.

3.5 Memes

The term “meme” was coined by the biologist Richard Dawkins in *The Selfish Gene*, and has since become popular in philosophy (e.g. Dennett 1991, Blackmore 1999), and has even made it into the Oxford Dictionary, with the origin: “Greek *mimema* ‘that which is imitated’, on the pattern of *gene*”. A meme is a “unit of cultural transmission”, in Dawkins’ original sense. “Examples of memes are tunes, ideas, catch-phrases, clothes, fashions, ways of making pots or of building arches. Just as genes propagate themselves in the gene pool by leaping from body to body via sperms or eggs, so memes propagate themselves in the meme pool by leaping from brain to brain via a process which, in the broad sense, can be called imitation.” (Dawkins 1976:192).

The comparison of memes and genes has advantages and disadvantages. The advantage is that it draws attention to the way in which ideas evolve. This is very helpful in extending principles from systems theory beyond physical objects and into a more abstract domain. The disadvantage is that it encourages a tendency to think of memes as "things" of a certain type. Daniel Dennett, for example, speaks of memes as parasites that "take up residence in an individual brain, shaping its tendencies and thereby turning it into a mind" (1991:252). Bennett and Hacker indicate some of the problems with this approach (2003:431-435). "The claim that human consciousness is a complex of meme-effects in brains that can best be understood as the operation of a von Neumannesque virtual machine implemented in the parallel architecture of the brain is, we suggest, quite literally meaningless." (2003:435).

I would like to suggest a way of looking at the concept of memes that may avoid such problems, while retaining the advantages of the connection with genes. Memes are not analogous to genes, or at least the analogy seems somewhat problematic. Rather, both memes and genes are ways of describing probabilistic attractors. Instead of looking to genes to help understand memes, we should look at what the two concepts have in common, as ways of talking about probability. Similarly, evolution in general should be characterised in terms of probability: it need not always use a genotype/phenotype mechanism. Evolution of memes is potentially quicker and much more fluid than biological evolution.

A meme is a behavioural attractor. It gains this identity in some functional context that depends on the observer. It will be physically instantiated in some way, although its position in a nonlinear context means it shares in properties beyond its own physical ones. For example, there is a much higher likelihood that people will sit on a chair in a waiting room, rather than sing the chair a tune. However, a mentally disturbed person, or someone from some hypothetical isolated society, might interact with the chair in unexpected ways. Given this sense of the term, memes are not only encountered by humans; although our "meme environment" or "meme context" is vastly more complicated than that of simpler open systems engaging in entropy-management behaviour, especially thanks to language and other nonlinear aspects of consciousness (and obviously no simpler systems use the word “meme” in abstract description of behavioural phenomena).

Entropy management implies systems that must be managed. Open systems with similar purposes will tend to act with a given system in similar ways. However, this interaction is only probabilistic (although for simple objects such as clothing or a knife, the probability of particular types of interaction may be very high, across all cultures). As elements in an ongoing feedback process of entropy management, these attractors can evolve over time.

When we teach someone how to read music (for example), we are not transferring a meme. Rather, we are adding to the contextual basis upon which that person interacts with memes. Now the person can sing from a sheet of music, write down musical notation, and so on. (Both actions can be considered as new instances of memes that can attract certain types of behaviour, such as singing along, or reading the written notation.) Often, we will teach others by demonstrating the appropriate types of behaviour on some instance of the meme, although some topologically related model (such as a picture or verbal description) can also be used. But often a person will come across a standard behavioural approach to a meme independently, through analogy with another meme, or simple trial and error.

Memes require such a context in order to behave probabilistically as attractors. There needs to be some ordered process for which they have relevance. As such, memes should not be considered as existing independently of a behavioural context. The term provides a way of talking about patterns of behaviour. There is little point arguing over whether a butter knife is a different meme from a table knife: the distinction is a matter of convenience, depending on functional needs in the course of a particular analysis.

3.5.1 Fractal memes

Since they are attractors, and can undergo feedback quickly in a complex environment as they evolve, memes can take on a fractal character. That is, they can acquire a complicated self-similar internal topological structure that is capable of great flexibility and detail. A musical note may be called a meme, since it has a probabilistic effect on behaviour (touching the key of a piano, for example). But the wider meme of which it is one element, namely music, has a fantastically complex structure that can result in a great variety of distinct (yet related) forms of behaviour.

It is one of the distinct characteristics of human beings that we make use of such fractal memes, with two of the most obvious examples being language and music. Others might include fashion, art, mathematics, or ritual. Fractal memes can provide for flexibility of behaviour in the face of nonlinearity: in use of tools, for example. In particular, they can be used to describe extremely complicated situations; and they are therefore very well suited to communication of relevant information between open systems. I will return to this topic in the next chapter.

3.6 Consciousness

> Everything from our useless appendix to the weak backs we have through standing upright should remind us that evolution is not a process of inevitable perfection; in fact, evolution is a process of Heath Robinson make-do, a series of compromises by which we attempt to do the best we can with a set of incompatible goals.
>
> Robin Dunbar (1996:193)

The topic of consciousness is a difficult one. D. J. Chalmers refers to the problem of why there should be consciousness at all (in the sense of our lived experience of the world) as "the hard problem" (Chalmers 1995). It seems that there is something about (for example) the colours we see or the moods we feel that cannot adequately be captured by words, and which we cannot imagine sharing fully with anyone in quite the same way as we experience it. There is something which one might call "private" about our consciousness, although the term seems not quite to fit. On the one hand, we can talk about our sensations and moods quite well, and when we feel that we can't express exactly what we mean, often we are not quite sure we understand ourselves what we want to say. On the other hand, it does not quite make sense to speak of something being "private" that can *never* be shared. We can imagine trespassing on private land, but it is hard to imagine how one could share the experience of seeing a colour, needing no confirmation by verbal or other means to be sure that the experience was shared.

There seems to be a clear problem here with informational horizons due to complexity: "the human brain is the most complex object we are aware of in the universe" (Glynn 1999:7). To fully model a working brain could well result in the creation of an artificial intelligence, while leaving us none the wiser as to the conscious experience of that intelligence. However, consciousness is rather an unusual subject, and "the hard problem" does not *just* result from complexity. Two interesting topics related to this point are the mereological fallacy, and neurophenomenology

3.6.1 The mereological fallacy

M. R. Bennett and P. M. S. Hacker argue that there is a great deal of conceptual confusion in this area. Taking an approach influenced by Wittgenstein, they suggest that "misunderstandings concerning the concepts of *inner* and *outer*, *direct* and *indirect*, *privileged access* and *introspection*, *subjectivity* and *privacy*, collectively support a wholly misguided picture of the mental" (Bennett and Hacker 2003:97).

The reason for such misunderstandings is what Bennett and Hacker term the mereological fallacy: "a fallacy of ascribing to a part properties that can be ascribed intelligibly only to the whole of which that part is a part" (Bennett and Hacker 2003:111). This is a warning not to carelessly use psychological terms with reference to the brain rather than the mind. When this fallacy is committed, "like Cartesianism, contemporary neuroscience conceives of mental events, state and processes as occurring, obtaining or going on *in* a human being - in particular, *in his brain* - rather than conceiving of mental states as states *of the person*, of mental acts or activities as acts and activities *of the human being*, and of mental processes as processes undergone, gone through or engaged in *by a person*" (Bennett and Hacker 2003:112).

Explaining the "why" of the mind rather than the brain requires a description in another domain. "These descriptions will cite multitudinous factors: past and prospective events that in given circumstances may constitute the agent's reasons for action; the agent's desires, intentions, goals and purposes; his tendencies, habits and customs, and the moral and social norms to which he conforms" (Bennett and Hacker 2003:365). This is certainly not to say that the mind does not depend on the brain, or some other equally complex physical pattern of feedback processing. It is rather an attempt to avoid a particular type of confusion that can arise from injudicious use of words.

One might even say that the reason "the hard problem" is considered to be a problem that needs solving is due to the mereological fallacy. I will return to this topic in section 4.3.

3.6.2 Neurophenomenology

A topic which seems to me to be closely related to Bennett and Hacker's distinction between the mind and the brain is the concept of neurophenomenology (Laughlin et. al. 1990, Varela and Thompson 2003). The key concept for Varela and Thompson is *embodiment*. Consciousness relies on an underlying complex system, but there is no particular reason to define hard limits to this system at the edges of the brain, the nervous system, or even the body: "the processes crucial for consciousness may cut across the brain-body-world divisions, rather than being limited to neural events in the head" (Varela and Thompson 2003:279).

The complexity of the brain and the rest of the nervous system means that it must be doing a lot of the work that makes consciousness possible. However, taking into account the mereological fallacy, we need not limit the physical system underlying consciousness to neurons. Other physical components (such as spindles of muscle fibres (Cotterill 2003)) may be able to play a role, if the topology permits.

Neurophenomenology certainly seems to be compatible with Bennett and Hacker's approach: "no neural process *per se* can be "the place where consciousness happens", because conscious experience occurs only at the level of the whole embodied and situated agent" (Varela and Thompson 2003:281).

3.6.3 Nonlinearity and consciousness

One of the most important methods in the scientific study of the relationship between brain and mind has been cognitive neuropsychology, which attempts to track down the specific machinery required for different aspects of consciousness. One approach has been to study the effects of various injuries to the brain (Glynn 1999:310), but such methods have been supplemented by new ways of measuring brain activity (such as functional magnetic resonance imaging, which monitors blood flow and oxygen consumption in the brain).

The physical modularity indicated by such methods seems to fit well with our experience of consciousness. One way of illustrating the connection might be the strange experiences we have when brain functions are disassociated when falling asleep, intoxicated, concussed, etc. Another example could be William James' idea of the "specious present" (1891), the conscious sensation of the "now" as an ongoing flow of experience, despite the fact that the underlying neural events may not be simultaneous (the so-called "binding problem" (Glynn 1999:412)).

However, perhaps the clearest illustration of the nonlinearity of consciousness is our ability to make associations. Any conscious sensory experience can be accompanied by other modalities of consciousness: memories, emotions or moods, verbal descriptions, awareness of number, and so on. It is difficult to say exactly how these different modalities are associated, in conscious terms: they simply seem to arise together. Although we might say, "I associated his face with that comedian, and felt amused", the perception, memory and emotion might well have all come up at the same time, as far as we can consciously tell.

We can also "prompt" these kinds of conscious associations through interior monologue, or simply by the right kind of attention. We can observe any kind of object or scene, and attempt to "conjure up" associations, which then arise in consciousness spontaneously. We cannot be sure whether we will experience a memory, think of some other object, or even become aware of some piece of music. This ability is very useful when engaged in some creative activity, such as storytelling. It is also useful for analysis. In his discussion of polysynthetic languages (in which verbs contain a lot of extra information on the subject, object, etc.), Mark Baker gives the example of how to say “I am a student” in Mohawk – *katerihwaiénstha*’ (Baker 2001:88). This is a single word that literally means “I habitually cause myself to have ideas”.

It seems to me that failure to discard weak associations may be implicated in the paranoia suffered by schizophrenics, etc. Dreaming seems to make use of relatively free associations. (The precise purpose of dreaming is still debated, although disruption of dreaming seems adversely to affect memory.) One might speculate that the brain makes many associations, then filters them on some probabilistic basis, with only those that seem useful appearing in consciousness. In the case of dreaming or mental illness, this filtering may be weaker than normal. However, overly strict filtering might result in lower levels of creativity, due to failure to find unexpected connections.

In this section I wish to focus on three points that I think are particularly helpful in understanding the role of nonlinear association in consciousness: synaesthesia, evolution of memes (particularly as influenced by language) and new social pressures.

3.6.3.1 Synaesthesia

The condition termed synaesthesia was named by Francis Galton in 1880, but has only become a popular subject for neuroscientists recently. “There have been approximately 157 peer-reviewed synaesthesia papers published in the past 25 years; of these, 75% have been published within the past five years and 35% within the past 18 months.” (Simner 2007:27).

In synaesthesia, “the normal barriers keeping the sensory modalities apart are absent, allowing spectacular crosstalk between sight, sound, taste, touch and smell.” (Lehrer 2007:48). Synaesthesia results in unusual associations between words, letters, numbers, musical notes and aspects of sensory consciousness. Associations may even involve attribution of personality or gender (Simner & Holenstein 2007). Estimates of frequency among the population range from 1 in 2000 to 1 in 20 (Simner et. al 2006). The frequency is difficult to pin down because associations across modalities are common, even among those who do not qualify as syanaesthetes: "If asked which of… two figures… is a "bouba" and which is a "kiki," 98 percent of all respondents choose the blob as a bouba and the other [spikier shape] as a kiki." (Ramachandran and Hubbard 2006:59).

Synaesthesia "is thought to arise from a neurodevelopmental tendency to preserve or develop atypical interactions between brain regions that normally do not communicate" (Simner & Holenstein 2007:694). Synaesthetes perform well at finding targets in jumbles of words and letters, if they are able to associate colours to them, for example (Ramachandran and Hubbard 2003a). This unusual case demonstrates something we take for granted, and even perhaps find difficult to notice at all, because it seems so natural: the nonlinear association in consciousness of a variety of very different modalities. A synaesthete sees letters as coloured, or can perform mathematical calculations by visualising numbers arranged in three-dimensional space, which can be very useful in certain circumstances. However, the role of association of different modalities is also important in the activities that seem characteristic of consciousness, such as remembering, imagining or analysing.

Of particular interest is the recent emphasis by researchers on the importance of linguistic features to synaesthesia (Simner 2007, Rich et. al 2005). Language, and particularly linguistic association, seems central to consciousness.

3.6.3.1.1 A note on associations

Any particular modality can be described as background independent. For example, my optician tells me that my eyes are different sizes (my vision is fairly poor, naturally). It seems to me that my left eye sees objects as redder than my right. There is not really any sense in which I could say that one of them had more "accurate" colour vision than the other. A modality does not require absolute measurement, but rather *differentiation*. It is differentiation that allows functional applicability: the ability to deal with probabilities. What counts is the topology, the possibilities of information flow. Synaesthetic association between simple categories such as letters, colours, numbers, tones, scents, tastes, spatial positions, and so on, is no doubt permitted by their similar topologies.

3.6.3.2 Early social pressures helping the evolution of language

One possible connection between game theory and nonlinear complexity in consciousness is what psychologists call "theory of mind" (Baron-Cohen 1995). Theory of mind refers to one's understanding of others' awareness. We can be aware that others know we are aware of what they are thinking (at least after the age of four or so) and so the loop goes, until it becomes too complex to keep track of.

Behaviour of open systems has a particular "energy signature", due to the presence of statistically-unlikely levels of order. In the woods at night, one would have a greater reaction to the sound of regular footsteps than to the sound of a running stream. It is important to keep track of the behaviour of other open systems if one is to avoid being preyed upon; and one must recognise when other open systems are aware of one's presence, to be an effective hunter. Further iterations allow deception, whether conscious or instinctive (as in the case of a Killdeer plover behaving as if wounded and giving distress signals to lure predators from its nest). Such strategies provide game-theoretic pressure for evolution of the ability to represent nonlinear relationships.

Theories of the influence of game theory on the evolution of the mind are sometimes called “Machiavellian intelligence” theories (Byrne & Whiten 1988).

The need for game-theoretic entropy management may be behind the evolution of language, and consciousness in general. According to anthropologist Robin Dunbar, the impetus for developing language arose when environmental pressures forced the apes from which humans descend to the edge of the African forests. Grooming, the process by which apes and other primates manage social interaction, became too time-consuming for the large group sizes needed for survival in this more hostile environment. The solution was to replace direct grooming with vocalisations.

> "Language… allows us to reach more individuals at the same time; it allows us to exchange information about our social world so that we can keep track of what's happening among members of our social network (as well as keeping track of social cheats); it allows us to engage in self-advertising in a way that monkeys and apes cannot; and last but not least, it seems to allow us to produce the reinforcing effects of grooming (opiate release) from a distance." (Dunbar 1996:192)

Dunbar has found a connection between the group size for various primates and the size of the neocortex, the most recently-evolved part of the mammalian brain within the cerebral cortex (1993). (It seems to be the cerebral cortex that is responsible for our ability to make associations between different conscious modalities (Glynn 1999:212).) As group size increases, possible social relations increase combinatorially. The need to balance entropy management within larger groups (Dunbar proposes a figure of 150, according to the size of the human neocortex and other evidence) might have resulted in evolutionary pressure for more complex representation.

Of course, creating models of social interaction is an important activity still: “To get some idea of how important gossip is, we monitored conversations in a university refectory, scoring the topic at 30-second intervals. Social relationships and personal experiences accounted for about 70 per cent of conversation time. About half of this was devoted to the relationships or experiences of third parties." (Dunbar 1992:31). Awareness of the purposes of others surely makes up a large proportion of the contents of consciousness over an average day, from anticipating traffic flow to watching the television news.

3.6.3.3 The later evolution of language and other memes

According to Julian Jaynes, "Because language *must* make dramatic changes in man's attention to things and persons, because it allows a transfer of information of enormous scope, it must have developed over a period that shows archaeologically that such changes occurred." (1976:130). Although language may have started out with vocalisations to coordinate small groups, the earliest examples of nonlinear memes involving symbolic representation[11] do not appear around thirty to sixty thousand years ago (Stringer, C and MicKie, R. 1996; Mithen 1996). One can perhaps assume that before this time, language was very simple. Small hunter-gatherer groups have neither the need nor the means to develop very complex language: the number of possible functionally distinct referents was small, and only oral or ostensive forms of teaching were possible, restricting the spread of innovation. While knowledge of plants, animals, hunting techniques, and so forth, may be advanced, language relating to technology, complex social organisation, and other topics will necessarily be limited: not least because the possible extent of non-linear combination will be relatively small. Even cave paintings and incised decoration are not highly nonlinear,

[11] According to Ian Watts, inference of symbolism in early populations requires "evidence for repeated patterning and intentionality" (1999:113).

although they are amenable to evolution through copying and combination, and presumably were accompanied by increased complexity of language.

Language, considered as a behavioural attractor, becomes highly complex with the invention of writing, which arose from the use of pictograms in formal labelling systems. Pictograms can be used to help construct complex memes in this way, but are restricted by lack of detail in representation. “Once symbol became sign around 3700 BC, graphic art began to ‘talk’... A picture of an ox had originally meant only ‘ox’, prompting one to say the word aloud. With the new rebus principle, one began pronouncing sounds that no longer conveyed only the graphic image.” (Fischer 2001:34). The rebus principle is the move from pictorial to phonetic representation in writing.[12] This allowed much more accurate symbolic representation of language, and much increased the possibilities for evolution and feedback among a wider population.

Writing certainly enabled the construction of complex memes that gave advantages for social organisation, such as laws and detailed contracts. While we can assume low levels of literacy in early civilisations, the rebus principle greatly reduces the number of signs that must be learned, while greatly increasing the grammatical complexity that can be represented. What is more, the durable nature of written description ought to have permitted feedback between language and other memes. Descriptions developed for one purpose could be applied to another.

3.6.3.4 Social pressures and consciousness

The transition from hunter-gatherer groups to settlements based on agriculture

[12] Chinese writing has a slightly different history. Chinese writing probably came out of pictograms used for divination, before the first millennium BCE. Chinese characters often have phonetic elements, and also are nonlinear in that they tend to be made of several components. Many elements are not derived from pictures. A character usually stands for one concept or name, or group of such, related functionally or by historical accident. It is also possible to use Chinese characters phonetically, as in transliterations of Buddhist terms from Sanskrit, or of foreign proper names. (See Norman 1988).

somewhat preceded the advent of writing. Large settlements increase the possibility of meme propagation, feedback, and persistence, and this probably helped in the independent discovery of the writing attractor in Mesopotamia, China, etc.

The establishment of large settlements resulted in great game-theoretic pressures, which needed to be dealt with through new memes. One obvious candidate is religion, which (in its game-theoretic implications) rather resembles Jeremy Bentham's idea of the Panopticon, a prison that he proposed at the end of the eighteenth century, in which the prisoners may always be being watched (1995). Religion has the advantage of making use of our evolved tendency to follow dominant individuals, making it much more easily available as an attractor than nonlinear memes such as democracy.

There is some evidence that even in the early stages of civilisation, subjective consciousness as we know it may not have existed. In the somewhat controversial (yet certainly thought provoking) view of Jaynes, at this time the associations between language and sensory modalities were not yet well integrated (1976). Language, and the meme environment in general, had not yet evolved to anywhere like its current level of complexity. Language still served a largely social function, being used for commands, requests, and the simple descriptions thereby required. The earliest form of the integration of language with other modalities, according to Jaynes, involved auditory hallucinations of such commands. This contributed to the establishment of religion for purposes of organising and controlling large groups: people heard the voices of gods or spirits giving them instructions, and indeed could invoke such hallucinations for functional purposes using the preserved bodies of leaders, or images and statues.

Whether in the course of external pressures such as war or drought, or simply in the course of meme evolution, many large theocratic states organised on this basis in

China, Egypt, Mesopotamia, Mycenae, and the Indus Valley eventually collapsed, giving rise to the civilisations of what Karl Jaspers called the Axial Age (1962). In this period, from around the start of the first millennium BCE, language became more integrated with other modalities, and auditory hallucinations became less common, becoming the domain of professional mediums and oracles. This was accompanied by the development of formal religion and complex political systems, and the beginnings of science.

While religion remained a source of taboos and superstitions, there was a general reduction in highly impractical or counterproductive religious practices such as human sacrifice and ritualised warfare. Questions arose as to the efficacy of religious ritual, not in terms of results (the success or failure of a particular ritual or performer) but in terms of the underlying logic of ritual itself.[13] Religion became more philosophical as its organisational function was partially taken over by new technological and cultural developments. Art began to address more everyday subjects, becoming less entwined with religion, with one notable trend in many cultures being a movement away from depictions of simplified faces with grossly oversized eyes, which Jaynes believed were more conducive to generating hallucinations.

The Axial Age was not a time of transformation into any kind of *modern* scientific mindset, which only becomes recognisable after the Renaissance. However, noting that the Indo-European root of the word "science" is related to the Greek *schizein* and the Latin *scindere* meaning "to split", and the Sanskrit *chyati* meaning "he cuts off", one may say that science took its first steps during the Axial Age, in the sense of the creation of bodies of systematic knowledge based on an analytical process

[13] Awareness of ritual as different from other actions is a mark of the rational mindset. Bourdieu (1977, 1990) and, earlier, Wittgenstein (see Tambiah 1990) argue that rituals need not be rationally aimed at achieving a goal, but can be instinctual or habitual actions that "make sense" without additional abstract

of dividing up and classifying phenomena into abstract schemes.[14]

Whether one accepts all the details of Jaynes thesis or not, it was during this period of civilisational transformation that highly nonlinear memes first appeared. It seems that requirements for this process were a large, stable, relatively prosperous population to help meme propagation, the game-theoretic pressures of organising and controlling such populations, and the increasing sophistication of language and writing that accompanied this enriched meme environment. Following Jaynes, a further factor may have been the gradual integration of this more sophisticated language with other modalities, perhaps even thereby giving rise to subjective consciousness. Certainly there does not seem to be a great deal of evidence in literature for phenomena such as introspection[15] before the Axial Age (Jaynes mostly discusses literature of the Near East and Greece, but see Fingarette 1972 for a discussion of lack of introspection in the *Analects* of Confucius).

3.6.4 Consciousness and morality

Certainly we seem to give more weight to the purposes of our fellow humans than animals, plants, computers, and other open systems. I do not believe this is simply "species-ism", an unfounded prejudice in favour of those who are similar to ourselves. We have a sense that fulfilment or frustration of purposes *matters* more to humans. Spilling a glass of water on your laptop is not an act with the same moral consequences as murdering someone (although it does have *some* moral consequences, if desired or undesired). This is a difficult question, and I cannot hope to give a fully satisfactory answer here.

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explanation.

[14] Astronomy and other forms of measurement had already been practised for centuries, but in a very practical fashion, rather than as an abstract discipline with its own internal logic.

[15] I take introspection to be paying attention to and describing one's conscious experience, with implicit

In my view, the moral weight we recognise as accompanying conscious purposes results from the extreme nonlinearity of conscious associations. This results in what can perhaps only be called *deeper* suffering or happiness than less-complex open systems, particularly due to the integration of very detailed memory and imagination, which comes with its own emotional content. Another factor is our behavioural integration with extremely nonlinear memes, which provide further levels of association and range of possible desires.

For humans, morality is concerned with freedom: what we want and don't want. Humans are capable of wanting more, and wanting it more deeply, than other open systems: of having desires that are more detailed and complex, involving memories of the past and imagination of other potential alternatives, in an environment that is much richer. Our entropy management encompasses choices and possibilities that other open systems cannot begin to be aware of. In the end, however, it seems to me that this point is not something that can be proven; it is something that is recognised.

3.7 Conclusion

Relevance was initially defined in broad terms as information (change) that is relevant to the survival of metastability. I then presented a very quick sketch of a possible basis for moving from this physical sense of relevance to a theory of morality applicable to human purposes. The good in this theory revolves around entropy management, which permits the application of game theory for the purpose of balancing the good. This has various advantages in coping with unavoidable informational limits that might otherwise trouble a formal theory of morality.

I also introduced a new way of looking at the concept of memes:

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or explicit acknowledgement that it represents a particular perspective or standpoint.

physically-instantiated probabilistic attractors for the behaviour of open systems. This avoids some of the "mereological" problems of situating memes "within" consciousness.

Thirdly, I discussed some points relating to consciousness: the need to avoid confusion between brain processes and thought processes when doing philosophy; the importance to consciousness of associations between different modalities; and some of the social and meme pressures that may have led to the evolution of language, writing, and perhaps even consciousness itself.

3.7.1 The subjective character of consciousness

> We say a dog is afraid his master will beat him; but not, he is afraid his master will beat him to-morrow. Why not?
>
> Ludwig Wittgenstein (1953:§650)

Recent studies of synaesthesia emphasising the role of language (reviewed in Simner 2007), together with Jaynes' suggestion that conscious linguistic modalities only became fully integrated relatively recently, suggest to me a way of helping to explain the character of consciousness. Perhaps consciousness arose as a means of integrating topologically-simple sensory and emotional modalities with other, nonlinear ones such as language, which evolved more recently as society, culture and technology took off with the advent of agricultural settlements.

As language followed its feedback path to nonlinearity, in tandem with other complex memes such as art and commerce, and with the increasing complexity of social relations, integration may have required a new "arena" of comparison in the mind. This would have allowed phenomena such as interior monologue to help tease out the social structure of a large group, or verbal self-interrogation to recall memories or meme techniques, as well as helping to organise and classify elements of the increasingly complex meme environment. Before this, language would have still been closely related to vocalisation: a practical tool for giving orders and signalling immediate states. Consciousness would have resulted from a co-opting of language to help deal with the increasing complexity of the social and meme environment. It permits information-sharing between modalities that are topologically quite distinct, especially in terms of complexity.

What we call consciousness would be the subjective “space” that permits such associations. One possible explanation for why language might have the ability to open this “space” could be found in a remark of Lev Vygotsky: “A word does not refer to a single object but to a group or class of objects. Each word is therefore already a generalization. Generalization is a verbal act of thought and reflects reality in quite another way than sensation and perception.” (In Sacks 1989:48). This conscious “space” itself has no direct entropy-management purpose (though it permits more and “deeper” desires on the part of the conscious subject). This could help explain the confusions that can arise in philosophy through describing consciousness using language developed to talk about things. This point brings us to the final, and shortest, chapter of this thesis: the Signal Elements Category.

4. The Signal Elements Category

> I can know what someone else is thinking, not what I am thinking.
>
> It is correct to say "I know what you are thinking", and wrong to say "I know what I am thinking."
>
> (A whole cloud of philosophy condensed into a drop of grammar.)
>
> Ludwig Wittgenstein (1953: 222)

The third category of topics which I wish to propose as useful to the systems approach to philosophy is the Signal Elements Category. The title of this category is intended to emphasise that the memes we use for deliberate transmission of information (for purposes of cooperation, competition, and other reasons) are made up of discrete elements organised in a way that can be described using a grammar or other formal system of categorisation, which may have a nonlinear character.

All human activity involves entropy management, by definition. Expending energy will result in an alteration of probabilities. One can classify aspects of activity in various ways; one is in terms of a basic physical aspect and a signalling aspect. The signalling aspect will make use of some kind of grammar: a topologically nonlinear arrangement of elements, chosen from among other possibilities, in order to evoke associations or some other reaction.

One may find any number of examples simply by glancing about. Books are designed physically to be read in good light, their pages to remain in a certain order, to have a certain level of resistance to damage, and so on. These are the more basic physical aspect of the human activity that the book represents. Books also have images on the cover, a choice of typefaces, perhaps a photo of the author in a particular pose, and of course their main *raison d'être*, their meaningful contents. A building is built of various materials so as to stay stable while being partly permeable to light, air, those people or animals who use it, and so on. It also has a certain architectural character, will be decorated in a particular style, and may have the name of the occupant or a description of its purpose posted somewhere on its exterior. A dance requires expenditure of energy in movement, the right footwear, a space for performance, adequate lighting, and so on; and it is designed to express certain emotions or ideas. Possible examples are endless; although not all activity *need* have a signalling element, of course.

The Signal Elements Category is a subset of the Relevance Category: the aim of communication is still to create order or disorder. However, it merits standing alone due to its particular nonlinear structure, and the type of uses to which it is put. In physical terms, a painting hanging in a gallery is a relatively ordered structure, created for purposes that will ultimately be instantiated through variations of order and disorder, whether earning money or changing the emotional state of the viewer. But there is a lot more that one can say about a painting!

There is a great deal that could be said on the precise topology of nonlinear memes that are used for communication, of course, from art to music to logic to fashion. Guerino Mazzola gives a detailed analysis of the topological grammar of music in *The Topos of Music: Geometric Logic of Concepts, Theory, and Performance* (2002) for example. Here I simply wish to make a few remarks about such memes as attractors, and cover three points regarding the consequences for such memes of the nature of information.

4.1 Grammar

Memes are attractors for behaviour; however, they vary in complexity. Looking at examples of the most complex memes, we can determine rules that govern their generation, although conscious awareness of these rules may not be needed for that generation. This property has obvious advantages: memes can be generated very flexibly, to direct behaviour in precise and subtle ways, yet the ability to produce such memes can be easily taught or picked up.

Categories of grammars have been formalised by Chomsky (1956, 1986) and others on a topological basis. This has brought a mathematical precision to the long-recognised branching structure used to analyse phrases and sentences, and helped make grammar a topic in computation theory. It is interesting to note that the expansion of one type of grammar, context-free grammar (the rules of which are simpler than those of natural languages (Shieber 1985)) has proven useful in modelling the fractal topology of plants (Prusinkiewicz and Aristid 1990) and sea-shells (Meinhardt 1995).

There is a broader sense of grammar, by which we say that advertisements or cartoons or even “no smoking” signs have their own grammar. As Wittgenstein says, “Grammar tells what kind of object anything is. (Theology as grammar).” Grammar requires differentiated elements (such as English words) that can be organised in a way that can be described using rules (such as English syntax) – but differentiation is also a form of relation

4.1.1 Parameters

Chomsky introduced the concept of “parameter” to linguistic grammar. A parameter is “a choice point in the general recipe for a human language.... an ingredient that can be added in order to make one kind of language or left out in order to make another kind.” (Baker 2001:57). For example, it is possible to add a phrase to a new word in order to make another phrase; and the phrase will either go before the new word (as in English) or after it (as in Japanese). This choice defines the “head directionality parameter”. Parameters provide a way of giving simple explanations as to how languages differ. One or two differences in parameters will lead to great variation in the final structure of the utterances produced by two different languages, due to the nonlinearity inherent in the rule-based generation process. These parameters could be viewed as defining attractors in the phase space of the language: one is even called the “verb attraction parameter”, which decides whether verbs are attracted to the position of tense auxiliaries, or *vice versa*.

4.1.2 Universal Grammar

Another of Chomsky’s contributions to linguistics is the concept of Universal Grammar, which looks for connections between common elements in languages (such as parameters) and language acquisition. Cook and Newson write that “The physical basis of UG means that it is part of the human genetic inheritance, a part of biology rather than psychology”, and go on to quote Chomsky: “universal grammar is part of the genotype specifying one aspect of the initial state of the human mind and brain” (Cook & Newson 1996:186). Discussing systematic and complete historical changes in grammar due to changes in parameters, Baker writes that “it seems more plausible to think that parameters reflect natural regularities of the human mind, born into all of us, rather than the results of cultural decision, whether conscious or unconscious.” (Baker 2001:203).

Viewing grammar in terms of probabilities and attractors provides a possible route for escaping the need to explain regularities between languages (and other complex memes such as types of music) entirely in terms of genetics. It might be possible to give a probabilistic account of the mutual influence of different generative rules on the overall phase space of the grammar, and map that either to neuronal hardwiring after birth, or even to leave it in the realm of the likelihood of particular physical instantiations of the meme.

A complex-dynamics approach might make Universal Grammar less "universal" and more probabilistic – but on the other hand, it might provide a way to incorporate unexpected features such as supplementing linguistic grammar with prosody in the Pirahã language of Brazil (Colapinto 2006) or gesture in Tasmanian languages (Lévy-Bruhl, 1985:179).

4.1.3 Lexical semantics

It seems to me complex dynamics might also have some application to lexical semantics, the study of the relationships between word meanings, "perhaps the most problematic and least-developed area of contemporary linguistics." (Baker 2001:204). Word meaning can be fluid, because "meaning is constrained by both the sentence structure as a whole and the meaning of the other words around it." (ibid 205). However, words can be organised into semantic networks on the basis of logical relationships. Polysemy (fluidity of meaning) being a key topic in areas such as Deconstruction and Semiotics, it is perhaps possible that some concepts from complex dynamics could be of use in these areas. However, I do not have enough knowledge of these fields to pursue this suggestion further here.

4.2 Escaping the physicality of information

Memes used for communication, since they arise from the activity of open systems, are affected by constraints such as the physicality of information in terms of their actual instantiation. For example, it is impossible to precisely plot a fractal shape that has infinite complexity, and likewise we cannot graphically represent a point or a line except by means such as drawing a shape on paper or on a computer screen, which will have more than the one or two dimensions it technically should have. Multidimensional or extremely nonlinear phenomena may be very difficult or even impossible to represent: in some cases, complex phenomena can be shown to be impossible to model due to unavoidable constraints on computation such as the lifespan of the universe, or the amount of matter available therein to represent whatever is being modelled.

The very need to make this point implies that the internal logic of certain memes can avoid representing constraints due to the physicality of information, the nature of observation in a closed-system universe, and so on. It is possible to assume perfect knowledge, or infinite detail, or conflate knowledge with its object – whereas information actually received physically cannot be said to be "the same" as whatever originally caused it to propagate; and indeed the implication that information requires measurement, along with problems such as quantum indeterminacy, makes pinning down an ultimate "source" of information propagation very problematic.

In *Three Roads To Quantum Gravity* Lee Smolin gives an interesting account of the danger of failing to represent such constraints, in the history of quantum gravity theory (2000). During the development of Loop Quantum Gravity, Smolin and colleagues encountered problems trying to reconcile relativity theory (which Smolin argues is background-independent (Smolin 2007)) with string theory. They were able to proceed by taking into account constraints to information due to the nature of observation, which has been called the "relational approach" to quantum physics (Crane 1994). Carlo Rovelli says with regard to this approach, "The notion rejected here is the notion of absolute, or observer-independent, state of a system; equivalently, the notion of observer-independent values of physical quantities.... by abandoning such a notion (in favor of the weaker notion of state – and values of physical quantities – relative to something), quantum mechanics makes much more sense." (1996:1637).

This point need not be restricted to quantum physics. Any formal scheme comes out of a particular context, and is used for given purposes. Because this is unavoidable, it cannot be considered a *criticism* of formal modelling or analysis to make this observation. Still, the implications of the physical instantiation of formal schemes, and the inevitable simplification that modelling implies, ought to be kept in mind.

McCluhan's analysis of the effects that physical media can have on the message being transmitted is related to the point that representation must be physically instantiated somehow. The related observations of some "postmodernist" writers such as Jean Baudrillard on the social effects of communication, and the relationship between sign and reality, are also relevant in this regard (1994).

Pierre Bourdieu's description of the "synoptic illusion" may also be pertinent here (1977:97 ff.). Anthropological analysis has a tendency to create synopses, to abstract what seem to be the important features of belief systems, to organise things into a regular order, and then to hold the hidden assumption that the people whose beliefs are under examination are actually aware of such synopses, and act accordingly. However, the lived reality of beliefs and practices does not necessarily require an awareness of any particular overarching abstraction or map representing the system.

4.2.1 This thesis as communication

These points naturally apply to the current thesis. The observations herein are in the form of typical Western academic "discourse", for example. There is undoubtedly some lack of clarity at certain points regarding the distinction between the "natural" or the "physical" and "representations" or "models" thereof. There are two solutions to such problems. One can tie oneself into linguistic knots, inserting qualifiers upon qualifiers, without really improving matters; or one can be content to accept that in practical terms, the distinction is clear enough for the *purposes* of this thesis.

The realm of the physical is that to which informational horizons apply. The realm of representation is the formal world of the model. The physical form of this thesis belongs to the former (the Physical Category), while the content falls into both the Relevance Category (being submitted as part of the requirements for academic assessment, for example) and the Signal Elements Category. It is very hard to avoid confusion arising from such distinctions when talking about topics in the Physical Category, in particular. Werner Heisenberg quotes Einstein as saying, "Whether you can observe a thing or not depends on the theory which you use. It is the theory which decides what can be observed." (Bethe 1989:39).

I have tried to keep in mind, in writing, the probabilistic nature of truth, due to the necessity that information be *observed*; and so to use phrases such as "can be described as", and so forth. Indeed, the classification of the chapters of this thesis into three "categories" is intended to emphasise that this thesis represents a way of looking at things, of dividing up modes of observation. Perhaps the most one can say is that there is a certain topological resemblance between the topics in each category, as mentioned in section 1.4.5. The title of this thesis, "Using Systems Theory To Do Philosophy", should also be taken in this spirit of acknowledging context and purpose.

4.3 The primacy of consciousness

The question of the consequences of determinism for free will arose in section 3.4.3. It seems appealing to say that a deterministic universe would mean we have no free will; but we cannot say whether the universe is fully deterministic or not, and it is difficult to imagine what difference it would make to morality if we were somehow to find out tomorrow that it were. If we did discover that the universe were deterministic, and decided that no-one "really" had any moral responsibility for anything, there would be the difficulty of describing what it *would* mean for someone to "really" have responsibility. When one cannot explain what the contrary case would be, it becomes doubtful if there is really a problem.

There is a somewhat similar issue in the question of communicating the subjective nature of conscious experience. We would like to say that there is something about the smell of coffee (to take an example from Wittgenstein) that cannot be expressed in words; but we have no practical difficulties in talking about the smell of coffee, and it is hard to pin down what would be the contrary case that solved this "problem".

The question of "what something is like" is a rather pernicious one in philosophy. It is simple to talk about whether one thing is like another (compare them) using words; and certainly conscious experiences are differentiated (we can tell coffee from whiskey) – but comparing things by verbal description is not the same as having two different conscious experiences. The phrase "what something is like" has the potential to mislead. If a friend were to say, "Seeing the look on his face was like winning a million dollars", we would be considered rather pedantic if we responded, "But you've never won a million dollars, and even if you had, how could you be sure you were remembering the experience properly when you made the comparison?".

Sometimes philosophers use the term “qualia” as a way of talking about “what something is like”. The number of different qualia must be enormous, since there is one for every differentiable conscious experience. The term is so broad as to make it very difficult to say anything about how qualia are related. The main effect of the word seems to be to turn an experience into an object. To quote Wittgenstein again, “The decisive movement in the conjuring trick has been made, and it was the very one that we thought quite innocent.” (1953 §308). An *object* is identified in the course of entropy management on some basis of relevance, but the *experience of recognising an object* is not necessarily itself an object. Some of the further problems with this way of putting things are detailed by Bennett and Hacker (2003:261 ff.).

In section 3.7.1 I suggested that language might play a role in generating consciousness, which could be described as a “space” in which different modalities can be associated. Oliver Sacks gives some support for this way of looking at consciousness in his accounts of deaf children who, for some reason, were never taught any form of language, including sign language (1989:37ff). Sacks describes such children as having great difficulty in understanding references to times other than the present, hypotheses or possibilities. They find it hard to imagine, reflect, or plan. Wittgenstein likewise writes “Can only those hope who can talk? Only those who have mastered the use of a language. That is to say, the phenomena of hope are modes of this complicated form of life. (If a concept refers to a character of human handwriting, it has no application to beings that do not write.)” (1953:174). But it is not a paradox for language to be necessary for consciousness while at the same time being something different from conscious experience.

Wittgenstein says, “Words are also deeds.” (ibid:§546) and “Language is an instrument.” (ibid:§569.). Consciousness is not a deed, but one way in which purposes are determined. In a way, it has "primacy" over language: there would be no need for language if there were no observers. Language can be used to create nonlinear models that are extremely useful. But it is a tool used for particular purposes. Purposes themselves arise in the probabilistic flow of metastability.

4.3.1 Physicalism and morality

A related point touches on the argument one sometimes hears along the lines of "If the physical universe is all there is, then we are just random collections of matter and energy, there is no meaning, and nothing matters". One would hope that this argument would only be used as *reductio ad absurdum*, since the speaker must intend to say something meaningful in making it. However, one sometimes comes across this kind of statement accompanied with a touch of fear or dread, or even awe.

The main problem with this kind of statement is the pejorative use of the word "random". As I hope to have shown in this thesis, physicalism does not insist that things are random, but can explain how order arises, and from order, relevance, meaning and morality. Furthermore, there seems to be here another version of the problem encountered in the discussion of free will, and in the discussion regarding the expression of "what something is like": namely, that it is hard to specify how the introduction of the non-physical would help matters. Statements that "nothing matters" if there is no "plan" for the universe are particularly confusing. A plan is simply a way of talking about purposes, and it is unclear why a plan for the progress of the universe as a whole should permit morality, while the purposes of those of us within it cannot.

Statements such as "nothing matters" or "everything is meaningless" are absurd, if taken literally rather than poetically. The contradiction of trying to make a meaningful statement that denies meaning betrays a grudging recognition that meaning requires observation (that is, a context that determines relevance) and at the same time, a failure to fully appreciate the implications of that point. Similarly, an Internet search for the phrase “from the point of view of the universe” gives half-a-million results. But the universe does not have a point of view, beyond that of observers within it.

5. Conclusion

In the course of this thesis, I have tried to address H. T. Odum's claim that "General systems theories are a way of reuniting the fields that seek to generalize knowledge." (1995:368). I have attempted to show connections between a large number of different approaches to science and philosophy, and to argue that philosophy ought to take account of some of the findings of these areas of science. I see the incorporation into philosophy of new theories of information (such as the relational approach to quantum physics) as being compatible with Wittgenstein's aim in philosophy, "To shew the fly the way out of the fly-bottle." (1953:§309). That is, to understand what it is to be an observer, and not to be misled by language and other forms of communication, which need not take account of the nature of information for observers in a closed-system universe.

I also hope to have given some indication of a way of founding a theory of morality, which can explain why some things are right and others wrong, upon a thoroughgoing physicalism. Although there has not been room here to give a great many examples of how one could apply this theory to various hypothetical moral dilemmas, in any case I believe such an approach is rather overused in moral philosophy. More important is discussion of practical game-theoretic mechanisms that can help reliably balance competing purposes.

Entropy management is one topic that recurs throughout this thesis. There are two reasons for this. One is that probabilistic change can be found throughout the universe, from the quantum scale to clusters of galaxies. The other is the possibility of metastability, which permits relevance, and the existence of open systems.

Analysis of probability and its management by open systems is relevant to a very wide range of topics in science, philosophy, and other areas of enquiry. I hope to have shown that an understanding of the implications of the closed-system nature of the universe and the physicality of information for observers is useful for explaining ideas as diverse as time, order, meaning and free will, just to name a few of the subjects covered in this thesis.

5.1 Entropy management and consciousness

I should make one final point regarding the applicability of entropy management to consciousness. It might be argued that entropy management is not relevant to explanations of consciousness, because of Bennett and Hacker's mereological fallacy: applying scientific descriptions that rightly apply to the *objects* of consciousness to consciousness itself. This argument might also be applied to the use of "entropy management", "purpose" and "desire" as interchangeable at certain points.

However, Bennett and Hacker acknowledge that consciousness depends on a physical system for its existence, and this certainly would be hard to deny from the changes to conscious experience that arise from illness, intoxication, injury, sleep, death, and other changes affecting the nervous system. I am not trying to claim that entropy management is *all there is* to conscious purposes and desires; only that the latter depend on the former. Fulfilling some purpose will require entropy management. My stress on the role of entropy management is not intended to preclude philosophy of purpose or will, but rather to indicate some areas in which such philosophies may have to take the scientific findings into account if they wish to remain compatible with physicalism.

5.1.1 *Being and Time*

One philosophical program which I believe gives an account of consciousness and the will which is compatible with physical constraints to information, and other topics discussed in this thesis, is that of Martin Heidegger's *Being and Time* (1962). A few examples include Heidegger's concepts of being-there (*Dasein*), care (*Sorge*) and the hermeneutic circle (*Hermeneutische Zirkel*).

Dasein can be compared with embodied or situated consciousness – being-in-the-world (*In-der-Welt-sein*). Care seems to me to resonate with the idea of purpose as based on entropy management by an open-system observer in a particular context.[16] The hermeneutic circle has similarities with the idea that meaning always requires a context: the circle arises because "there can be no interpretation (and so, no understanding) that is free of pre-conception, and… this is not a limitation to be rued but an essential precondition of any comprehending relation to the world" (Mulhall 1996:87). According to Heidegger, "The 'circle' in understanding belongs to the structure of meaning, and the latter phenomenon is rooted in the existential constitution of *Dasein* - being in the world" (Heidegger 1962:195).

Dasein must always be present in its world, and has no choice but to care about this world. This echoes the idea that entropy management is unavoidable. Mulhall says that "the conditionedness of human existence… [is] fundamentally a matter of being fated to a self and to a world of other selves and objects about which one cannot choose not to be concerned" (Mulhall 1996:112). Chapter VI of *Being and Time* is entitled "Care as the Being of *Dasein*". According to Heidegger, "*Dasein* is an entity for which, in its Being, that Being is an issue" (Heidegger 1962:236). This is because *Dasein* is

[16] Dasein's being is "being-in", and examples of "being-in" that represent Sorge include "having to do with something, producing something, attending to something and looking after it, making use of something, giving something up and letting it go, undertaking, accomplishing, evincing, interrogating,

aware of possibilities and potentials, which connects *Dasein* and care with time, characterised as a horizon.

Many other examples of possible connections between *Being and Time* and the relationship between entropy management and consciousness could be given, such as the distinction between objects being "ready-to-hand" (*zuhanden*) and "present-at-hand" (*vorhanden*), or the distinction between *Dasein* and objects, which avoids the mereological fallacy: "*Dasein* does not fill up a bit of space as a Real Thing or item of equipment would, so that the boundaries dividing it from the surrounding space would themselves just define that space spatially. *Dasein* takes space in" (ibid:419).

However, Heidegger's approach to ethics has little connection with my proposed "Utilitarianism of entropy management with physical constraints to information". The ethics of *Being and Time* is rather impoverished. It consists largely of a preference for "authenticity" (*Eigentlichkeit*) over the "they" (*das Man*), which implies not being aware of one's situation as an embodied consciousness, but following conventions like a sleepwalker. While inauthenticity may be aesthetically unappealing, Heidegger does not provide any grounds for thinking it immoral. This does not stop him discussing such topics in an admonitory tone (use of words such as "must", referring to "our constant task", etc.) throughout the book, which I believe to be a weakness of the text.

5.1.2 *Chan* 禪 Buddhism

Another area which I would suggest is very apt for philosophical interpretation compatible with the ideas presented in this thesis is the literature of Chinese *Chan* Buddhism, in particular the "records of sayings" (*yulu* 語錄) literature from the

considering, discussing, determining" (Heidegger 1962:56).

Classical period (around 765 to 950 CE).

Chan literature is concerned both with the nature of conscious experience and the proper uses of language. It possesses an extremely rich technical vocabulary for discussing these topics. Being also a practical pedagogical tradition, *Chan* also contains many examples of misunderstandings of the nature of observation and communication, and methods for remedying such misunderstandings.

One may also say of *Chan* that it does not include a formal theory of morality. However, being part of Buddhism, it does deal with topics such as compassion, which are relevant game-theory concepts such as aid and harm.

So-called "mystical" traditions such as *Chan* have had very little intersection with Western philosophy (the influence of Daoism on Heidegger, described by Reinhard May (1996), is one exception). I believe that a better understanding of the topics discussed in this thesis would perhaps enable more dialogue between these two areas in the future.

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