OUR COMPLEX WORLD

UNDERSTANDING IT, LIVING IN IT, SUSTAINING IT

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DECLARATION

I, the undersigned, hereby declare that the work contained
in this assignment is my own original work that I have not
previously in its entirety or in part submitted at any
University for a degree.

Abstract

We live in a complex world. We have questions and face problems that
defy conventional reductionist approaches to finding answers and solutions.
This is because we find ourselves dealing with complex systems that are
dynamic, self-organizing and adaptive, while maintaining a balance between
static order and chaotic change.

The Earth, or Gaia, is such a system. So is the biosphere, and so is an ecosystem,
an economy, a business and any living organism, including *homo sapiens*. By
concentrating on the connections and interactions between entities, and not
things in themselves, complexity research is enabling us to grasp a better
understanding of the spontaneous, self-organizing dynamics of our world.
Complexity studies can have an enormous impact on the conduct of economics,
business and politics.

This thesis describes the characteristics of complex systems, analyzes the Earth
and its evolutionary story as a complex adaptive system, discusses how we can
harness complexity, and how through cooperating and caring we can survive and
even prosper in the world of today. A pluralistic moral 'world vision' is argued for,
founded on an ethics of universal compassion for all living things, that can lead to
responsible and pragmatic action.

As human beings, if we are to uplift the poor and restore and preserve the ecology
of the Earth, what will be required is a major transformation of our environmentally
destructive world economy into one that can sustain progress and human flourishing.
This will entail a change of mind and heart, a sense of global interdependence and
universal responsibility.

The challenges we face are immense. However, there are encouraging signs that
worldwide people are becoming increasingly aware of what is called for. More and
more people are showing their willingness to rise to the occasion. It is a time of
transition. It is complex, daunting, yet exciting.

Abstrak

Ons leef in 'n komplekse wêreld waarin ons gekonfronteer word met vrae en probleme wat nie beantwoord of opgelos kan word deur middel van die gebruiklike reduksionistiese benaderings nie. Die rede hiervoor is dat ons te make het met komplekse sisteme wat dinamies, selforganiserend en selfaanpassend is, terwyl dit tegelykertyd 'n balans handhaaf tussen statiese orde en chaotiese verandering.

Die aarde, of Gaia, is so 'n sisteem. Ook die biosfeer, 'n ekosisteem, 'n ekonomie, 'n besigheid en enige lewende organisme, insluitend *homo sapiens*, konstitueer komplekse sisteme. Daarom kan kompleksiteitsnavorsing, wat klem lê op die verbande en interaksies tussen entiteite, eerder as op die entiteite self, dit vir ons moontlik maak om die spontane en selforganiserende dinamiek van ons wêreld beter te begryp. Kompleksiteitstudies kan dan ook 'n enorme impak hê op die manier waarop ekonomie, besigheid en politiek beoefen word.

Hierdie tesis beskryf die eienskappe van komplekse sisteme, en analiseer die Aarde en haar evolusionêre verhaal as 'n komplekse, selfaanpassende sisteem. Verder bespreek dit ook hoe kompleksiteit ontgin kan word, en hoe ons deur samewerking en sorg kan oorleef en selfs floreer in die wêreld van vandag. Op grond van 'n etiek van universele medelye met alle lewende dinge word 'n pleidooi gelewer vir 'n pluralistiese morele "wêreldvisie" wat kan lei tot verantwoordelike en pragmatiese optrede.

Wat egter vereis word indien ons, as mense, armoede wil ophef en die ekologie van die aarde wil herstel en handhaaf, is 'n daadwerklike transformasie van ons omgewingsvernietigende wêreldekonomie in die rigting van 'n ekonomie wat vooruitgang en menslike florering kan onderhou. So 'n transformasie sal 'n verandering van denke en ingesteldheid vereis, asook 'n sin vir globale interafhanklikheid en universele verantwoordelikheid.

Dit is duidelik dat die uitdagings wat ons moet trotseer kolossaal is. Daar is egter bemoedigende tekens wêreldwyd wat aandui dat mense toenemend begin bewus raak van wat vereis word. Meer en meer mense toon hul bereidwilligheid om die situasie die hoof te bied. Dit is 'n tyd van verandering. Dit is 'n komplekse en angswekkende tyd, maar uiteindelik tog ook 'n opwindende tyd.

ACKNOWLEDGEMENTS

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Contents

CHAPTER ONE

INTRODUCTION

I think the next century will be the century of complexity.

Stephen Hawking[1]

The Oxford English Dictionary defines the word 'complex' to mean 'consisting of many different and connected parts; not easy to understand; complicated or intricate'.[2] This is a fair description, but the concept 'complexity' is far from unequivocal. A complex system is more than merely complicated. A system may consist of a vast number of components, but if it can be given a complete description in terms of its individual components it is complicated, not complex. In a complex system the interaction amongst components of the system and the interaction between the system and its environment are such that simply analyzing its constituent parts will not lead to a full understanding of the system. The whole is more than the sum of the parts. When different parts come together the net result is not only a whole containing parts, but something extra. This is the concept of synergy. (A man can run but on their own his legs could not.)

Relationships between the parts, and between the system and its environment are not fixed. They can change as a result of self-organization. New, emergent properties can develop as a consequence of interaction between the elements of a system as they come together and connect (Cilliers, 1998: ix-x).

Over the last twenty years the study of complex systems and complex phenomena has emerged as a recognized field of study in its own right. It is new, it is far ranging and it is difficult to define, even as to where its boundaries lie. But then, this is the very nature of complexity. Complexity research involves dealing with problems and questions that defy conventional approaches.

Why did the Berlin Wall come down so suddenly in 1989 leading to the collapse of communism so fast and so complete, ending the 40 years of Soviet hegemony in Eastern Europe?

Why have ancient species and ecosystems often remained stable in the fossil record for millions of years, and then suddenly transformed or died out? Evidence suggests that an asteroid impact upon the Earth caused the extinction of the dinosaurs and many other species at the end of the Cretaceous period, but many extinctions and transformations are not so readily explained.

How does the brain work? How can one and a half kilos of tissue give rise to consciousness?

How did life evolve three and a half billion years ago from inanimate matter?

Indeed, why does the universe exist? Why not nothing?

We do not know. What we do know is that in every case we are dealing with systems that are complex, in which spontaneous self-organization occurs from a myriad of interactions between components of the systems. Further more, such complex, self-organizing systems are adaptive rather than passive, trying to turn what happens into some kind of advantage. It is the dynamism of these complex, self-organizing, adaptive systems which distinguishes them from the merely complicated, such as a snowflake or a computer chip. They are more spontaneous, more disorderly and more 'alive'. But they are not chaotic. If they were the structure, coherence, self-organizing cohesiveness and emergent properties of complex systems would not be explainable.

Complex systems are systems that seem to bring order and chaos into a special kind of balance. This is often called 'the edge of chaos', the balancing point where the components of a system never quite lock into place, yet never quite dissolve into turbulence. There is a self-maintaining balance between a static order and chaotic change.

Complexity theory is a new way of looking at things, and as such tends to discard many traditional technical and mathematical approaches used in scientific analysis. A complex system unlike a complicated system, for example an aircraft, is a functional whole consisting of variable parts that need not have fixed relationships, fixed behaviours, or fixed quantities. Complex systems form the bulk of our world, and include living organisms, many inorganic natural systems, such as rivers, and social systems.

Critically interacting components of a complex system self-organize to form potentially evolving structures exhibiting a hierarchy of emergent properties. Complexity theory maintains that, in studying such systems as wholes, the traditional emphasis on simplification and reduction techniques is an inadequate basis for this type of work. Such techniques are valuable in investigatory work and data collection, but fail in their application at the system level, due to the inherent non-linearity of circular causation and the feedback effects characteristic of strongly interconnected complex systems. Thus, a holistic viewpoint is taken. The mode of study is synthesis rather than reductionism.

Complexity studies are pursued by researchers from many diverse backgrounds and specialist fields of expertise. In concentrating on the connections and interactions between entities and not things in themselves, complexity studies are concerned with the study of change in dynamic systems. Such studies are, therefore, especially applicable in the highly dynamic world of today (Lucas, 2000: 1).

To this end, in 1984 an eclectic group of scientists and economists got together to form the Santa Fe Institute, in Santa Fe, New Mexico, USA. It is a 'think tank' of like-minded researchers who share a vision of an underlying unity and a common theoretical framework for complexity that will illuminate nature and humankind alike. They believe that their research will lead to a new and greater understanding of the spontaneous, self-organizing dynamics of our world, and that this will have an enormous impact on the conduct of economics, business and even politics (Waldrop, 1992: 12-13).

Based on the work such researchers, in this thesis I will describe and analyze what is currently understood of complexity and complex systems. I will then evaluate the Earth as a complex adaptive system, (that is, a system with the capacity to evolve and adapt to its environment through self-organization). Also, I will discuss the application of complexity theory, and how an understanding of complexity can be of great value in living in our complex postmodern world. I will argue that moral pluralism and virtue ethics, in particular an ethics centred on compassion, is the appropriate foundation for living responsibly and thereby flourishing in an ecologically threatened world. We also need to be pragmatic. Finally, I will offer support to the many voices calling for the implementation of sustainable global economic policies, and measures to curb human population growth if the integrity and beauty of the Earth is to be preserved in order that humankind may survive, and hopefully flourish. However, to argue whether or not the Earth

itself and the biota in general would be better off without *homo sapiens* will not form part of this project.

In attempting to define complexity, I will distinguish between the simple and the complex. I will discuss the concepts of chaos and randomness and explain how the study of complexity differs from classical reductionist approaches. The structural characteristics of complex systems will then be defined and concepts such as the 'edge of chaos' and self-organization, self-organized criticality, adaptation and emergence will be explained. I will complete this descriptive work with a section on modelling as a vital methodology in complexity research, and a section on the exciting, if not somewhat daunting, subjects of artificial intelligence and artificial life.

My purpose in recording a detailed description of complexity and complex systems is to lay a foundation from which to analyze the Earth as a complex adaptive system, and the origin and evolution of life on our planet, in terms of our current knowledge concerning the behaviour of complex systems. How did we get to where we are? A better understanding of the complex nature of the Earth's history can only but help us as human beings adapt to the present, predict the future and from there make appropriate plans for action in terms of our own social systems.

In preparing this descriptive groundwork, and in later descriptive sections of my thesis, I have at times relied on only a limited number of information sources. Sometimes there are no others but even where there are, I make no apology for doing this. Rather than 'reinvent the wheel' I have selected what I have found and consider to be the best source on a particular topic, and then based my descriptive work and discussion on that particular work. For example, for me, Paul Cilliers's book *Complexity and Postmodernism* (1998) stands out in defining the key characteristics of complex systems and self-organization, as does John Holland's work on emergence in *Emergence: From Chaos to Order* (1998), and Stuart Kauffman's work on collective autocatalysis and the edge of chaos phenomena in *At Home in the Universe* (1995). (Incidentally, the term 'edge of chaos' has become something of a tiresome cliché, but I nevertheless find it useful in naming the transition zone between order and chaos where rich and interesting complex behaviour occurs.) The section on the Gaia hypothesis is of necessity derived from James Lovelock's books *Gaia: A New Look at Life on Earth* (1979, reissued 2000) and *The Ages of Gaia: A Biography of our Living Earth* (1988/1995). Stuart Kauffman's book was again invaluable in compiling the sections on the origins of life, evolution and coevolution. When discussing cooperation Robert Axelrod's widely praised book *The Evolution of*

4

Cooperation (1984) stands out in a class of its own for the insights derived from games of Prisoner's Dilemma (4.3).

There are numerous other books and papers on complexity, varying from the highly specialized and difficult to comprehend without specific experience in the field, to the very general. The latter, whilst often containing interesting and important information, tend to be written for a wide audience, in flamboyant language, and in the form of a story. Here I am thinking of Roger Lewin's *Complexity, Life at the Edge of Chaos* (1999), M. Mitchell Waldrop's *Complexity, the Emerging Science at the Edge of Order and Chaos* (1992*)*, and George Johnson's *Fire in the Mind, Science Faith and the Search for Order* (1996*)*. I agree with Paul Cilliers (1998: 147), that even Stuart Kauffman's *At Home in the Universe* contains a lot of flowery language and quasi-religious rhetoric. Nevertheless, it is a valuable source of first hand information on much of the excellent research work that he has conducted. At times I have the suspicion that certain books have been written to appeal to a cult following on the subject of complexity...particularly if it is poised at the edge of chaos.

Accordingly, it is because of the nature of much of what has been written on complexity that I have attempted, in the first part of my thesis (chapter 2), what I trust is a more coherent synthesis of the key characteristics of complexity.

In understanding the Earth as a complex adaptive system, I am fascinated by the work of James Lovelock and his Gaia hypothesis. However, he is incorrect in believing that when he initially presented it in 1968, it was an entirely 'new look at life on Earth' as the title of his first book suggests. One hundred and seventy one years earlier, in 1797, the German philosopher Friedrich Schelling, in his classic work *Naturphilosophie*, proposed that the whole of reality can be viewed as one single developing organism. Further, that the most significant steps in the process have been, first, the emergence of organic out of inorganic nature, and then, within organic nature, the emergence of man. The point he was making was that it is within the natural world that man has come into existence, and developed, and that he remains inextricably interwoven with it (Magee, 1997:281). Lovelock's term for the Earth as a complex adaptive system, namely 'Gaia', has stuck and is increasing, widely used. Following on from explaining the Gaia hypothesis I will discuss the origin of life, evolution, and the coevolution of living species from a complexist perspective (chapter 3).

5

As *homo sapiens* we are fellow travellers on 'spaceship Gaia' with all other living things on Earth. But we are not the 'raison d'être' of the Universe. Or, so I believe. As Mark Twain said in repose to Alfred Russell Wallace's anthropocentric theory, "if the Eiffel Tower were now representing the world's age, the skin of paint on the pinnacle knob at its summit would represent man's share of that age; and anybody would perceive that that skin was what the tower was built for".[3] Accordingly, in the second half (chapters 4 and 5) of my thesis I will address how we, vulnerable and dependent human beings, can prosper in a world consisting of a vast multitude of interconnections and relationships, both within our own social systems and within the natural biosphere. I will discuss the complexity of our socio-economic human world, the complexity of the business world, and how we can harness complexity. I will highlight the benefits of cooperation on all fronts, particularly when there is caring and compassion for others. An analysis of the ethical issues pertaining to our existence as social beings and our relationships with others, be they human or non-human, will then be undertaken. I will argue for moral pluralism and for living responsibly, guided by an ethic founded on compassion but tempered by pragmatism.

Finally, in the last chapter (6), cognisant of the complexity of the issues involved, I will support the call for economic development to be sustainable and for the preservation of both cultural diversity and biodiversity. I will highlight the urgent need for us to address the interconnected problems of human population growth and poverty, and the concomitant need for environmental preservation.

CHAPTER TWO

COMPLEX SYSTEMS

Complexity is a word we have invented for an order which is not understood.[4]

2.1 Defining Complexity

A dictionary definition of the word complex has been given, but it is clear from what has already been said that complexity cannot be simply defined. Over the last 50 years numerous definitions have been proposed, with little consensus reached. An understanding of the concept is best obtained by analyzing the characteristics of complex systems, and in that way to define what one means by complexity. Having already differentiated between complex and complicated it is important to distinguish complexity from simplicity and complexity from chaotic.

2.1.1 Simplicity and Complexity

Simplicity refers to the absence, or near absence of complexity. The word derives from an expression meaning 'once folded' whilst complexity comes from an expression meaning 'braided together'... although both the 'plic' for fold and the 'plex' for braid derive from the same Indo-European root 'plek'. Thus, it is no simpler to clearly define simplicity than it is to define complexity (Gell-Mann, 1994: 26-27).

A wonderful example of the simple underlying principle of nature is the law of gravity, specifically Einstein's general-relativistic theory of gravitation (even though most people regard that theory as anything but simple!). In the course of the physical evolution of the universe the phenomena of gravitation gave rise to the clumping of matter into galaxies and then into stars and planets, including the Earth. From the time of their formation, such bodies were already manifesting complexity, diversity, and individuality. Complex adaptive systems emerged, which in the case of the Earth was associated with the process of biological evolution resulting in the awesome diversity of species. Our own, *homo sapiens*, the most complex so far, has succeeded in discovering a great deal of the underlying simplicity, including the theory of gravitation itself.

7

Research on simplicity and complexity revolves around understanding the two concepts, their interrelationships and differences. It also includes evaluating the similarities and differences among complex adaptive systems, functioning in diverse processes. Diverse processes such as the origin of life on Earth, biological evolution, the behaviour of organisms in ecological systems, the operation of mammalian immune systems, the evolution of human societies, the behavior of investors in financial markets and the use of computers to design strategies or to make predictions based on past observations (Gell-Mann, 1994: 16-17). Complex adaptive systems emerge from existing systems, and thereby systems develop within systems, increasing the degree of complexity and resulting in a number of levels of complexity.

The distinction between 'simple' and complex' is not always as sharp as we intuitively think (Nicolis and Prigogine, 1989: 5). Many systems appear simple but on closer examination are extremely complex, (e.g. a leaf), whilst others appear complex but can be described simply, such as the internal combustion engine. Complexity results from the interaction between components of a system. The distinction between complex and simple often becomes a function of 'distance' from the system (Serra and Zanarini, 1990: 4-5); that is the kind of description we are using. A leaf is simple from afar but complex on close examination, but this is not to imply that complexity is only a function of our description. Complex systems do have characteristics that are not merely determined by the point of view of the observer, but it is important to take care when discussing complexity. The simple and complex often mask each other (Cilliers, 1998: 2-3).

When defining complexity it is necessary to specify the level of detail up to which the system is described, with finer details ignored. Physicists call it 'coarse graining'. Analogous to the 'grain' or sharpness of a photograph, the finer the grain the clearer the picture and the more detail that can be seen. A very coarse grained photograph will only give a rough impression of the subject matter. As to defining the complexity of a system under investigation, Murray Gell-Mann (1994: 30-32) illustrates it with an example of varying patterns of communications between a group of people, (say 'N' people, where N = 8 in Figure 1). It is presumed that all the people are treated alike, are represented in the diagram by dots, that the position of the dots is irrelevant, that two way communication between individuals is either allowed or not allowed and that this is represented by a line connecting dots.
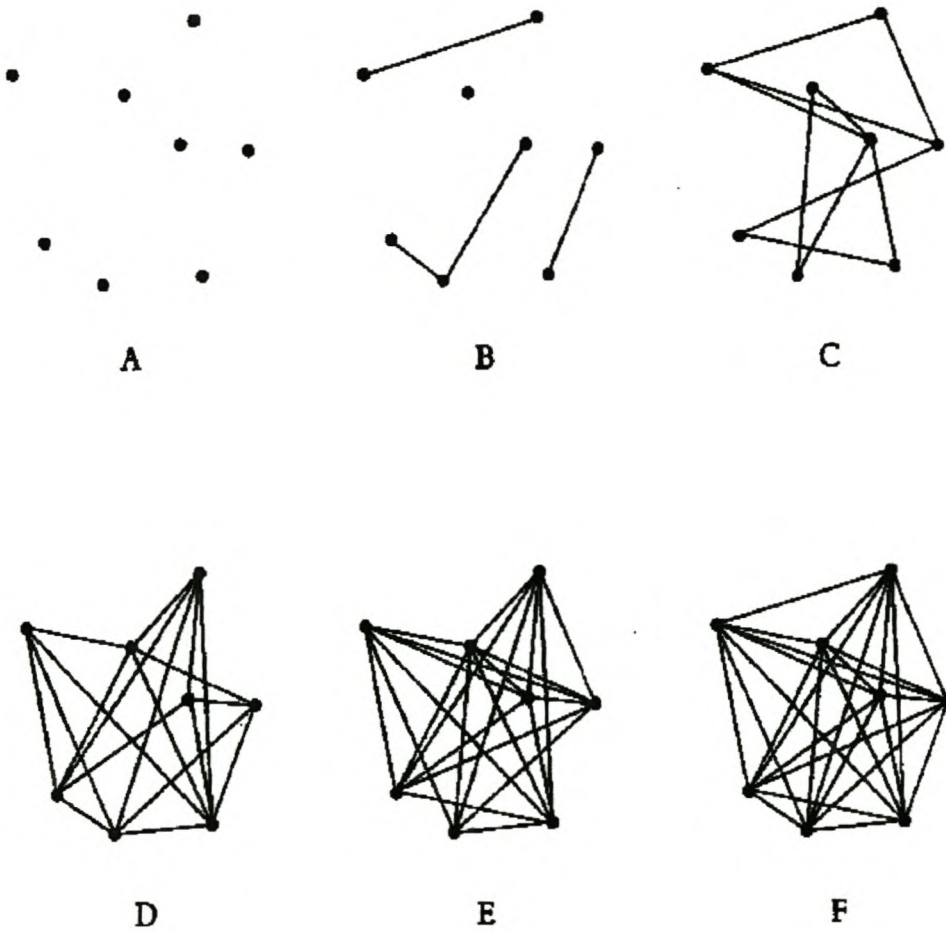
Figure 1.

Patterns for connecting eight dots.

Possible communication patterns are shown in Figure 1. A is clearly simple, B less simple, and C more complex. But what about F? Initially one would probably say it is the most complex, but is it? Isn't the property of all dots connected just as simple as no dots connected, and that A and F are equally simple and therefore the least complex of the group?

Such reasoning leads on to the suggestion that one way of defining the complexity of a system is to use the length of its description. In describing pattern F as "all dots connected" has a description as simple as its complement pattern A "no dots connected". Moreover, the

complexity of E is not all that different from its complement B since adding the word "complement" does not make the description significantly longer. The same is true of D and C. Thus, complementary patterns have similar complexity.

2.1.2 Chaos and Randomness

Chaos means complete disorder and confusion, and in physics it describes behaviour that is so unpredictable as to appear to be random, owing to great sensitivity to small changes in conditions.

Weather is the classic example. In weather systems many factors interact in complex ways, leading to notorious unpredictability. They are nonlinear systems and in such systems small inputs can lead to major consequences. This is the so-called butterfly effect: a butterfly over the Amazon rain forest in Brazil flaps its wings and sets in motion events that lead to a tornado in Texas[5]. But a second feature of nonlinear systems is that a very slight difference in initial conditions can produce very different outcomes. So, the next time the butterfly flaps its wings nothing meteorologically happens. This is the basis of unpredictability (Lewin, 1999:11).

The second law of thermodynamics states that the entropy in a system can only increase with time. Entropy can be regarded as the measure of the 'disorder' in a system. As a system transforms energy, less and less of it remains in a useable form, and the 'disorder' in the system increases. The concept of entropy is a complex one. Claude Shannon (1948,1949), the founder of modern information theory, used it as a measure for the information content of a message. He replaced 'energy' with 'information' in the equations of thermodynamics to show that the information in a message is equal to its 'entropy'. The more disorderly the message, the higher its information content. For example, if a message being transmitted as a string of digits consists of only three digits, this will soon be noticed by the receiver and become predictable: 146146146 ... The message is highly structured but the information content low. 146783,146783, 146783, is less simple/more complex but also quickly predictable. But 12439705348234845678671 … is not predictable (at least, not so far). The less readily a message is predictable, the higher the information content and the higher the 'entropy'. However, entropy theory is not an entirely adequate model for understanding complex systems such as human cognition (Katz and Dorfman, 1992: 167) where the intricate structure certainly cannot be equated with 'randomness'.

Gregory Chaitin (1975, 1987) in his reinterpretation of information theory, what he termed 'algorithmic information theory', defines randomness in terms of 'incompressibility', rather than in terms of unpredictability: "A series of numbers is random if the smallest algorithm capable of specifying it to a computer has about the same number of bits of information as the series itself" (Chaitin, 1975: 48). For example, if say, a sequence of a thousand numbers consists only of three, the programme would be:

Step 1. Print '3'.
Step 2. Repeat step1 a 999 times.

This programme is very much shorter than the original sequence, and therefore has a very low level of randomness. As the sequence of numbers becomes more complex, so does the programme to produce it, and when it is as long as the sequence, the sequence is said to be random. There can, of course, be many different programmes for any given sequence but we are only concerned with the shortest. The minimal programme is itself random by definition, since it cannot be reduced any further. Thus randomness is understood in terms of the denseness with which the information is compressed. Thus it provides us with a useful definition of complexity, for according to Chaitin (1975: 49): the complexity of a series is equal to the size of the minimal sequence necessary to produce that series (Cilliers, 1998: 8-9).

Even what at first appears to be a complex series is not necessarily so. Take the following series, even if there were a thousand numbers in the sequences:
A). 1 2 3 5 8 13 21 34 55 89 144 235 379 616 995 …
B). 1 2 3 5 7 11 13 17 23 29 31 37 41 43 47 …
Neither is very complex. The first is a fibonacci sequence, starting from 1. Each number in the sequence is the sum of the previous two. The second is the series of prime numbers starting from 1.
Thus the programmes would be:

A). Step 1. Print '1'.
   Step 2. Print '2'.
   Step 3. Add the two previous numbers and print.
   Step 4. Repeat 997 times.

11

B). Step 1. Print '1'.
   Step 2. Print '2'.
   Step 3. Print the next number that cannot be divided equally by a previous number other
       other than '1'.
   Step 4. Repeat 997 times.

Both have a similar level of complexity, and are much simpler than they appear at first glance. To a degree complexity is in the eye of the beholder. For anyone familiar with fibonacci numbers or prime numbers the underlying structure of the sequences would be immediately recognizable. For someone not familiar with them they may appear to be random, other than the fact that they are sequences of increasing numerical value.

Murray Gell-Mann uses the term 'effective complexity', for what is usually meant by 'complexity' as defined by the length of the concise description of the regularities of a system. That is, when a complex adaptive system is described by another system, for instance, by a human observer. As such effective complexity is not an intrinsic property of a system as it depends on the coarse graining, the language or coding employed by the observing system (1994: 370), and the knowledge and understanding of the world that is shared by the observers.

For example, for persons with an understanding of fibonacci numbers and prime numbers the aforegoing two sequences could be programmed in a single step each:

A). Step 1. List the first 1000 fibonacci numbers in sequence, starting with'1'.
B). Step 1. List the first 1000 prime numbers, starting with '1'.

Russell Standish (2001: 1-3) argues that context dependence is an inherent property of complexity. This smacks of subjectivity and is perhaps the reason why there has been little agreement on the exact meaning of the term. However, he is of the opinion that context dependence does not necessarily open us up to the curse of subjectivity. In many situations the equivalence relationships between similar entities in terms of their descriptions is well defined. For example, in biology the notion of species is reasonably well defined. In principle, together with a detailed knowledge of the genetic code, it could be used to estimate the relative complexity of different species.

2.1.3 Complexity Theory and the Study of Complexity

As Warren Weaver explained it 55 years ago (1948: 536-44) science up to the end of the 19th century succeeded in solving problems of simple systems, for example the movements of the solar system, while science of the first half of the 20th century learned by means of statistical analysis and probability theory, to deal with problems of 'disorganized' complexity. It was his contention that the task of science for the second half of the 20th century would be to develop means of investigating the dynamics of an 'organized' complexity, one not characterized by random behaviour and, therefore, not explicable by the rules of probability.

Weaver's prediction has been substantially confirmed by what is today categorized by the rubric 'complexity science'; although at this point in time I would hesitate to elevate the subject to the full status of a science. The amalgamation of approaches associated with this subject, such as cybernetics, information theory, cognitive science and various related fields, is now considered the model for unified transdisciplinary research projects of the future. This is the nature of research at the Santa Fe Institute, bringing together scholars in a number of fields such as biology, communications, economics, mathematics and physics.

Traditional scientific concepts of linear causality, determinism, and reductionism are being called into question. They are being replaced, or at least supplemented by complexity theory; that is by notions of circular causality, self-organization, indeterminacy, and the unpredictable emergence of order from disorder. Complexity theory is a systems theory and the study of complexity involves working towards developing a unified and methodological approach to investigate not just the often classical simplicities of the mechanistically structured material world, but also the complexities of biological, cognitive, and even social systems.

At the beginning of the 20th century the relativization, if not the breakdown, of the Newtonian worldview was seen as a crisis, but this new shift in emphasis has enabled the sciences to evaluate it rather as liberation. It has done this by enabling more nuanced and more comprehensive, yet still mathematically precise, descriptions of complex, nonlinear, dynamic phenomena. It has also enabled philosophers of science to theorize with greater rigor and precision epistemological problems that have traditionally bedeviled not only philosophers but also literary critics, and anyone concerned with interpretation and the problem of knowledge. The principal problem has been how to acknowledge the contingency and conceptual basis of

all description and interpretation without at the same time erring into 'anything goes' relativism. In light of the new developments in the sciences there are parallel developments commencing in the social sciences and the humanities (Rasch, 2000: 8-10). These developments should be encouraged, and the later sections of this thesis are in effect an attempt to apply an understanding of complexity theory to matters of an ethical nature.

2.2 The Characteristics of Complex Systems

2.2.1 The Structural Characteristics of Complex Systems

Paul Cilliers (1998: 3-5) has developed a very useful general description of the structural characteristics of complex systems. He lists 10 features in a description that he adapted from similar descriptions in Nicolis and Prigogine (1989), Serra and Zanarini (1990) and Jen (1990). Cilliers's ten features are as follows:

"(i) Complex systems consist of a large number of elements. When the number is relatively small, the behaviour of the elements can often be given a formal description in conventional terms. However, when the number becomes sufficiently large, conventional means (e.g. a system of differential equations) not only become impractical, they also cease to assist in any *understanding* of the system.

(ii) A large number of elements are necessary, but not sufficient. The grains of sand on a beach do not interest us as a complex system. In order to constitute a complex system, the elements have to interact, and this interaction has to be dynamic. A complex system changes with time. The interactions do not have to be *physical*; they can also be thought of as the transference of *information*.

(iii) The interaction is fairly rich, i.e. any element in the system influences, and is influenced by, quite a few other ones. The behaviour of the system, however, is not determined by the exact amount of interaction associated by specific elements. If there are enough elements in the system (of which some are redundant), a number of sparsely connected elements can perform the same function as that of one richly connected element.

14

(iv) The interactions themselves have a number of important characteristics. Firstly, they are *non-linear.* A large system of linear elements can usually be collapsed into an equivalent system that is very much smaller. Non-linearity also guarantees that small causes can have large results, and vice versa. It is a precondition of complexity.

(v) The interactions usually have a fairly short range; i.e. information is received primarily from intermediate neighbours. Long-range interaction is not impossible, but practical constraints usually force this consideration. This does not preclude wide-ranging *influence* – since the interaction is rich, the route from one element to any other can usually be covered in a few steps. As a result, the influence gets modulated along the way. It can be enhanced, suppressed or altered in a number of ways.

(vi) There are loops in the interactions. The effect of any activity can feed back on itself, sometimes after a number of intervening stages. This feedback can be positive (enhancing, stimulating) or negative (detracting, inhibiting). Both kinds are necessary. The technical term for this aspect of a complex system is *recurrency*.

(vii) Complex systems are usually open systems; i.e. they interact with their environment. As a matter of fact, it is often difficult to define the border of a complex system. Instead of being a characteristic of the system itself, the scope of the system is usually determined by the purpose of the *description* of the system, and is thus often influenced by the position of the observer. This process is called *framing*. Closed systems are usually merely complicated.

(viii) Complex systems operate far from conditions of equilibrium. There has to be a constant flow of energy to maintain the organization of the system and to ensure its survival. Equilibrium is another word for death.

(ix) Complex systems have a history. Not only do they evolve through time, but their past is co-responsible for their present behaviour. Any analysis of a complex system that ignores the dimension of time is incomplete, or at most a synchronic snapshot of a diachronic process.

(x) Each element in the system is ignorant of the behaviour of the system as a whole, it responds only to information that is available to it locally. This is vitally important. If each

15

element 'knew' what was happening to the system as a whole, all the complexity would have to be present *in that element.* This would entail a physical impossibility in the sense that a single element does not have the necessary capacity, or constitute a metaphysical move in the sense that 'consciousness' of the whole is contained in one particular unit. Complexity is the result of a rich interaction of simple elements that only respond to the limited information each of them are presented with. When we look at the behaviour of a complex system as a whole, our focus shifts from the individual element in the system to the complex structure of the system. The complexity emerges as a result of the patterns of interaction between the elements."

A point that needs to be made relates to the characteristic of a complex system usually being an open system. A complex system is considered open if it interacts with its environment, but many such systems are nevertheless operationally closed. This is the case with a living organism. The distinction will be discussed later when the notion of autopoiesis – the self-reproduction of a system's network of elements from the very same network of elements – is discussed (3.8).

Other researchers have approached the subject of description somewhat differently. For example, Vlad Dimitrov (2002) stresses what he considers are six crucially important laws 'ruling' the web of dynamics, interdependencies and relationships critical to the operation of complex systems. These laws he terms the laws of change, emergence, autopoiesis, growth-from-within, fractality and vorticity. For the purposes of this thesis a detailed exposition of his approach would be prone to confuse rather than add anything to what in my view, is a more coherent description developed by Cilliers. Hence, it will not be attempted.

In order to respond appropriately to its environment a complex system must be able to gather information about that environment and store it for future use. The structure of a complex system cannot consist of a random, chaotic collection of elements. The system must in some form *represent* the information. Cilliers argues for the notion of 'distributed representation' in terms of which the elements of the system have no representational meaning themselves, but only in terms of patterns of relationships with many other elements. He maintains that distributed representation is best implemented in connectionist (neural) networks, and he argues that these networks provide appropriate models for complex systems (Cilliers, 1998: 11).

Representation is an indispensable capability of a complex system. So is the notion of self-organization. A complex system, such as a living organism or a growing economy has to develop its structure and be able to adapt to it in order to cope with changes in the environment. Self- organization is the process whereby a system can develop a complex structure from fairly unstructured beginnings (Cilliers, 1998: 12). It will be discussed in detail in 2.2.3.

Having attempted to define complexity quantitatively (2.1.1 and 2.1.2), by identifying the ten structural characteristics of complex systems, and in noting two indispensable capabilities of complex systems one is now positioned to discuss complexity in a qualitative manner. I will move on to describe how complex systems come about, how they evolve, adapt and change through the process of self-organization, from which a complex structure spontaneously emerges and with it a degree of stability and order, a kind of balance at a transition phase between order and chaos, the often referred to 'edge of chaos'. But how can a system be dynamic, flexible and stable at one and the same time, poised at the edge of chaos?

2.2.2 The Edge of Chaos

Stuart Kauffman has done important work on autocatylitic sets, that is systems in which actions and reactions are aided (catalysed) by the product of another in a perpetuating sequence. His model, using a string of connected lightbulbs, is a useful connectionist model of a complex system and provides a sound basis from which to further discuss the properties of self-organization, self-organizing criticality, adaption and emergence evident in complex systems. Accordingly, I summarize in some detail much of what his research has revealed as recorded in his book: *At Home in the Universe* (1995: 75-92). (Modelling techniques for complex systems will be discussed in 2.3.)

Imagine there are 1000 lightbulbs randomly wired together. Turn the power on and depending on the wiring network, at the one extreme all the lightbulbs could be on while at the other they could be off. In between these two possibilities there is a myriad of possible combinations, 2^{1000} in fact, (a number so huge that if each combination were tried every second it would take over a trillion times the life of the universe to try them all). The range of possible behaviours is called a state space, the mathematical universe in which the system can roam. But to understand what is being investigated, Kauffman asks us to consider a simple network of only three lightbulbs –

17

1, 2, and 3 (fig. 2a). The arrows show which way the current, i.e. signals, flow; thus arrows point to bulb 1 from bulbs 2 and 3, signifying that bulb 1 receives signals from both bulbs 2 and 3.
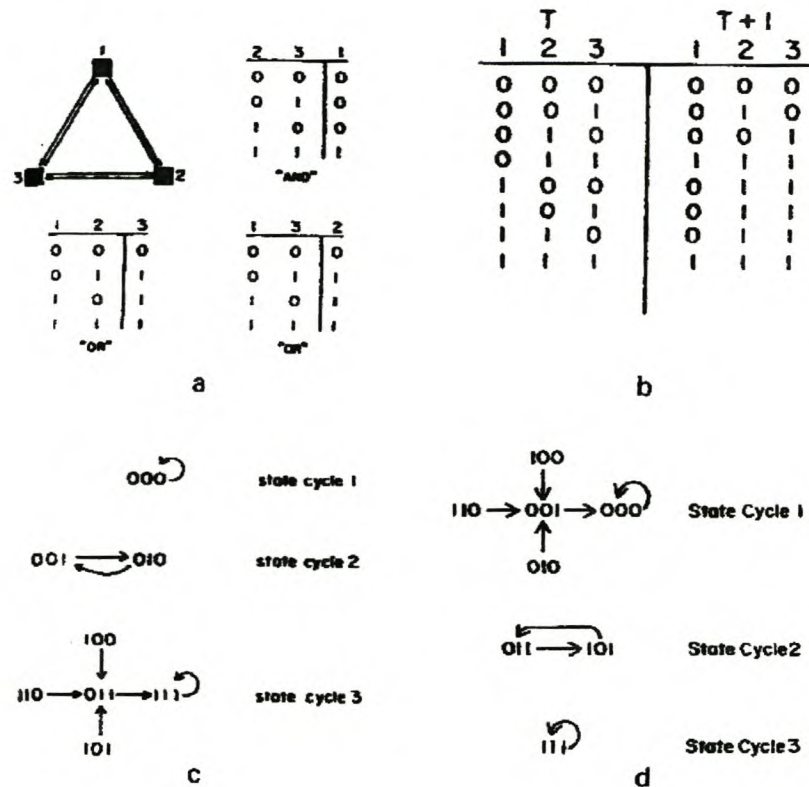
Figure 2.

A Boolean net. (a) The wiring diagram in a Boolean network with three binary elements, each an input to the other two. (b) The Boolean rules of (a) rewritten to show for all $(2^3) = 8$ states at time T, the activity assumed by each element at the next moment T+1. Read from left to right, this figure shows the successor state for each state. (c) The state transition graph of the autonomous Boolean network of (a) and (b), showing state transitions to successor states connected by arrows. (d) Effects of mutating the rule of element 2 from OR to AND.

Each lightbulb responds to the signals it receives and as each bulb can only be either on or off, this is represented as 1 or 0. Thus, there are four possible input patterns from its neighbours: 00, 01, 10 or 11. We can then construct a rule table specifying whether each bulb will be on (1)

18

or off (0) for each of the 4 signals. For example, bulb 1 might be active if both of its inputs from bulbs 2 *and* 3 were active the moment before. What one is dealing with is Boolean algebra and in the language of Boolean algebra, bulb 1 is an AND gate. Alternatively, we could choose instead that bulb 1 is a Boolean OR function: bulb 1 will be active the next moment if bulb 2 *or* bulb 3 *or* both were active the moment before.

To complete the specification of a Boolean network each lightbulb is assigned one of the possible Boolean functions, for example the AND to bulb 1 and the OR to bulbs 2 and 3 (Fig. 2a). The circuit is switched on and each bulb then reacts to the activities of its two inputs and adopts the state 1 or 0 specified by its Boolean function.

There are eight possible states that the network can assume (Fig. 2b). Read along the vertical columns, the right half of Fig. 2b specifies the Boolean rule governing each lightbulb. But read from left to right, Fig. 2b shows, for each current state at time T, the next state of the entire network one moment later, at T+1, when all the lightbulbs simultaneously adopt their new activities, 1 or 0. The system can be a finite number of states, in this case eight, and starting in any one state the system will flow through a sequence of states called a trajectory. As the system hits a state it has previously encountered the trajectory will repeat. Since the system is deterministic, it will cycle forever around a recurrent loop of states, called a state cycle.

Depending on the initial state various trajectories will be followed, falling at some point into an ever-repeating state cycle (Fig. 2c). The simplest would occur if the network fell immediately into a state cycle consisting of a single pattern of 1s or 0s. Such a state never changes, and is said to be stuck in a cycle of length 1. Alternatively the cycle length could be the total number of states in state space. In our three-bulb case the lights would twinkle through eight states, a pattern that would be soon detected, but in the case of 1000 bulbs we would have the hyperastronomical number of 2^{1000} states, totally unpredictable to us mere humans.

For autocatalytic sets to be orderly and to be stable enough to endure they must settle down into small state cycles. How can this happen? This is where the concept of an attractor comes in. Start a network with any of the possible initial states and after churning through a sequence of states it will settle into the same state, the same pattern of blinking. This state cycle is an attractor and the collection of trajectories which flow into it is called the basin of attraction, much like water in a catchment area flowing into a lake where the lake is the attractor and the

19

catchment area the basin of attraction. Just as a mountainous region may contain many lakes, a Boolean network may hold many state cycles, each draining into its own basin of attraction. In Fig. 2a-c this small network has three state cycles. The first state cycle has a single steady state (000), not draining any basin of trajectories. It is an isolated steady state. It can be reached only if the network starts there. The second state cycle has two states, (001) and (010) and oscillates between them. The third state cycle consists of the steady state (111), lying in a basin of attraction draining four other states (Fig. 2c). Start the network with any one of these patterns and it will quickly flow to the steady state and freeze up, displaying three lit bulbs.

Under the right conditions, these attractors can be the source of order in dynamic systems. As a system follows trajectories that inevitably flow into attractors, small attractors will 'trap' the system into small subregions of its stated space. Amongst a vast range of possible behaviours the system settles into an orderly few. But small attractors are not enough. For a complex, dynamic system such as an autocatylitic network, to be orderly it must exhibit homeostasis; that is it must be resistant to small perturbations. Attractors are the ultimate source of homeostasis as well, ensuring that a system is stable. In large networks, any state cycle typically drains an enormous basin; many states flow into the attractor. Moreover, the states within the basin can be very similar to the states in the state cycle to which they drain. Why is this important? Suppose one arbitrarily chooses a single lightbulb and flip to the opposite state. All or most such perturbations leave the system in the same basin of attraction, so the system will return to the same state cycle from which it was perturbed. This is the essence of homeostasis. State cycle 3 in Fig. 2c is stable in this way; if the network is in this basin, flipping the activity of any single bulb will have no long-term impact on its behaviour, for the system will return to the same state cycle.

But homeostatic stability does not always arise. State cycle 1, by contrast, is an isolated steady state and is unstable to the slightest perturbation. After any such flip the system is moved into a different basin of attraction, and if the system had the property that all attractors were unstable in this way, slight perturbations (the flapping of the butterfly's wings) would persistently push the system out of attractors on an endless never repeating journey through state space. The system would be chaotic. Thus, it is possible for systems that are Boolean networks to exhibit profound order; but Boolean networks can also exhibit profound chaos.

To summarize the results so far, two features of the way networks are constructed can control whether they are in an ordered regime, a chaotic regime, or a phase transition between them at the 'edge of chaos'. One feature is simply how many inputs control any lightbulb. If each lightbulb is controlled by only one or two other lightbulbs, if the network is 'sparsely connected', the system will exhibit stunning order. If controlled by many other lightbulbs it will be chaotic. So 'tuning' the connectivity of a network tunes whether one finds order or chaos. The second feature that controls the emergence of order or chaos is simple biases in the control rules (the AND and OR Boolean functions) themselves. Some tend to create orderly dynamics, others create chaos.

The next approach Kauffman, and others, took was to ask whether networks of a certain *general kind* exhibit order or chaos. To answer this question, the obvious approach is to carefully define the 'kind' of networks in question, and then use computers to simulate large numbers of networks chosen at random. One might, for example, study the pool of networks with 1000 bulbs (variable N) and 20 inputs per bulb (variable K). One then samples this ensemble by randomly assigning to each of the 1000 bulbs 20 inputs, and again randomly, one of the possible Boolean functions. The network's behaviour can now be studied, counting the number of attractors, the lengths of the attractors, their stability in the face of perturbations, and so forth. Sample by sample one builds up a picture of a family of Boolean nets, and then one changes the values of N and K and builds up another picture.

After years of study, networks with various parameters become familiar. Networks in which each lightbulb receives imput from only one other (K=1) show little of interest, quickly falling into very short state cycles and often only a single state, freezing up, with only a single pattern of illumination.

At the other end of the scale, where K=N, and each lightbulb receives an input from all lightbulbs including itself, one soon discovers that he length of the networks' state cycles is the square root of the number of states. Thus, for a network with only 200 binary variables – bulbs that can be on or off – there are 2^{200} or 10^{60} possible states and the length of the state cycles is of the order of 10^{30} states. This is another hyper-astronomical number, and we could never observe that the system had 'settled'.

What this means is that one is seeking laws that suffice to yield orderly dynamics. Our Boolean networks are non-equilibrium, open thermodynamic systems, but since a little network with only 200 lights would twinkle for eternity without repeating a pattern, order is in no way automatic in such systems.

However, such K = N networks do show signs of order. The number of attractors in a network is only N/e, where e is the base of natural logarithms, 2.71828. So a K = N network 200 binary states has only 74 attractors, very much smaller than the size of its state space of 10^{60}. Suppose then that the network is perturbed by flipping a bulb from off to on, or vice versa. In K=N networks, we would get the butterfly effect with 74 attractors, but with lengths of 10^{30} the tiny fluctuation will utterly change the evolution of the system. K = N networks are massively chaotic.

Most Boolean networks are chaotic. Even networks in which K is much less than N, K = 4 or K = 5 exhibit unpredictable, chaotic behaviour, but order arises suddenly in K = 2 networks. For such networks the length of state cycles is not the square root of the number of states, but approximately the square root of the number of binary variables. For example in a randomly constructed Boolean network with N = 100 000 lightbulbs, each receiving K = 2 inputs with each bulb assigned at random a Boolean function, the system has $2^{100\,000}$, or $10^{30\,000}$ possible states. But what happens? The massive network settles down and cycles through only 317 (the square root of 100 000), a miniscule fraction of the entire state space, about 1 divided by $10^{29\,998}$! Kauffman calls it 'order for free'.

Order expresses itself in these networks in diverse ways. Nearby states converge in state space in that two similar initial patterns will likely lie in the same basin of attraction, hence driving the system to the same attractor. Thus such systems do not show sensitivity to initial conditions; they are not chaotic. For the same reason these networks can undergo mutation that alters wiring or logic without veering into randomness. Most small mutations cause only small alteration in the behaviour of the network as basins of attraction change only slightly. Thus, such systems evolve readily. However, these networks are not too orderly. Unlike the K = 1 network, they are not frozen, but are capable of complex behaviour.

Working with Kauffman, Bernard Derrida and Gerard Weisbuch have shown that by tweaking a variable, P, there are ways to tune networks in which K is greater than 2 so that they become

orderly rather than chaotic. The P parameter is very simple. Fig. 3 shows three Boolean functions, each with four imputs. In each, the response of the regulated lightbulb must be specified for each of the 16 possible states of the four input lightbulbs, from (0000) to (1111).

A B C D	E
0 0 0 0	0
0 0 0 1	1
0 0 1 0	0
0 0 1 1	1
0 1 0 0	0
0 1 0 1	1
0 1 1 0	1
0 1 1 1	0
1 0 0 0	1
1 0 0 1	0
1 0 1 0	0
1 0 1 1	1
1 1 0 0	0
1 1 0 1	0
1 1 1 0	1
1 1 1 1	1

a

A B C D	E
0 0 0 0	0
0 0 0 1	0
0 0 1 0	0
0 0 1 1	0
0 1 0 0	0
0 1 0 1	0
0 1 1 0	0
0 1 1 1	0
1 0 0 0	1
1 0 0 1	0
1 0 1 0	0
1 0 1 1	0
1 1 0 0	0
1 1 0 1	0
1 1 1 0	0
1 1 1 1	0

b

A B C D	E
0 0 0 0	1
0 0 0 1	1
0 0 1 0	1
0 0 1 1	0
0 1 0 0	1
0 1 0 1	1
0 1 1 0	1
0 1 1 1	1
1 0 0 0	1
1 0 0 1	1
1 0 1 0	1
1 0 1 1	1
1 1 0 0	1
1 1 0 1	1
1 1 1 0	1
1 1 1 1	1

c

Figure 3.

Tinkering with the P parameter. (a) A Boolean function of four inputs, in which eight of the 16 input configurations yield a 0 response, while 8 of the 16 yield a 1 response. P = 8/16 = 0.5. (b) The response is 0 for 15 of the possible 16 input configurations. P =15/16 = 0.9375. (c) Fifteen of the 16 possible input configurations yield a 1 response. P = 15/16 = 0.9375.

For the Boolean function shown in Fig. 3a, half the responses of the regulated lightbulb are 1 and half are 0. For the Boolean function in Fig. 3b, 15 of the responses are 0, and only a single input pattern gets a 1 response from the regulated lightbulb. The Boolean function in Fig. 3c is similar to that in Fig. 3b except that the preferred response is 1, not 0. P is the parameter that measures the bias away from the half 1, half 0 response pattern. Thus in Fig. 3a P = 8/16 or 0.5 and in both Figs. 3b an 3b P = 15/16, or 0.9375.

As different networks are built up with increasing P biases from the no bias 0.5 to the maximum 1.0 networks with P = 0.5, or only slightly greater, are chaotic while networks with P near 1.0 are

orderly. This can be seen in the limit case when P = 1.0 for the bulbs are of only two types. One set respond with a 0, the other set with a 1, to any input pattern. So, starting the network in any state at all the network freezes into a corresponding pattern of 0 and 1 values and remains in that steady state, ordered regime, indefinitely. When P = 0.5, such networks with many inputs per lightbulb are in a chaotic regime, twinkling away for eternity. The critical value of P where the network will switch from chaotic to ordered is a poised state of balance on the edge of chaos.

From what has been explained so far it is perhaps to be expected that the phase transition from order to chaos along the P axis between P = 0.5 and 1.0 is sharp and experimental work confirms this, as is shown in fig. 4 for 400 lightbulbs.
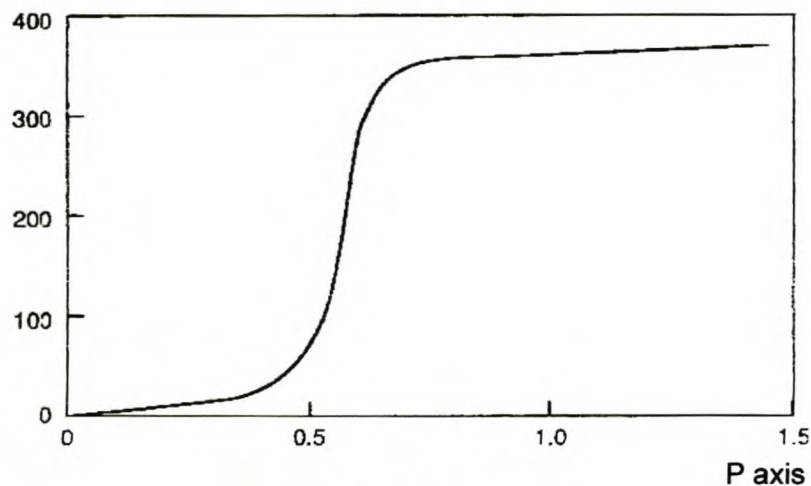
Figure 4
A phase transition.

When the number of lightbulbs is small the steepest part of the curve, as P starts to exceed 0.5, is shallow, but as the number of lightbulbs increases, from say, 400 to 100 million, the steep part of the sigmoidal curve approaches vertical. There will be a giant cluster of lightbulbs frozen into a fixed activity, 0 or 1. If this giant cluster forms we have order, not chaos, but near the phase transition, at the edge of chaos the most complex behaviour occurs orderly enough for stability, but full of flexibility and surprise.

To visualize what happens Kauffman suggests that two colours be substituted for the two behaviours, red for the fixed bulbs and green for the twinkling ones. Thus, in a chaotic regime,

24

say an N = 1 000, K = 20 network, there will be only a few very small clusters, or islands, of frozen red bulbs in a vast sea of twinkling green bulbs. In an ordered regime, say an N = 100 000, K = 2 network, at first most of the lights will be twinkling green, but as the network converges onto its state cycle, then orbits the cycle, more and more of the lightbulbs settle into fixed states, frozen on or off. Most of the lightbulbs will now be coloured red in the form of a giant interconnected cluster, with a few scattered isolated islands of twinkling green.

It is now possible to explain the sensitivity to changes in initial conditions in chaotic networks and the lack of sensitivity to such perturbations in ordered networks. If a single lightbulb is flipped one can follow the cascading changes radiating from the perturbation. In the chaotic regime when a lightbulb is flipped, the consequences cascade throughout the unfrozen green sea, creating massive changes in the activity patterns of the lightbulbs. But the system is too chaotic to coordinate behavior between distant sites and few new frozen islands of red would form or existing ones join up. In the ordered regime the converse happens. The rippling changes cannot penetrate a frozen sea of red blocking off the twinkling green islands from one another. Perturbations can cascade within each island but rarely propagate any further, thus exhibiting homeostasis. This leaves us with the edge of chaos. Here the twinkling unfrozen islands are in tendrils of contact. Flipping any light bulb may send signals in small or large cascades of change across the system to distant sites, so the behaviour in time and across the webbed network can become coordinated.

Kauffman's hypothesis is that:

>   the reason complex systems exist on, or in the ordered regime near, the edge
>   of chaos is because evolution takes them there.

He and co-workers are using computer simulations in an attempt to verify it but so far it is no more than a fascinating working hypothesis, not a 'proven' universal law. Nevertheless, the tendency of systems to move towards criticality results in an increase in complexity. In other words, once a system has the capacity to self-organize, there is a 'natural' drive to optimize the system. Kauffman's work attempts to show that this is an intrinsic characteristic of complex systems (Cilliers, 1998: 98).

The order that emerges in enormous, randomly assembled, interlinked networks of binary variables is almost certainly the harbinger of similar emergent order in whole varieties of

complex systems. Only now is the power of self-organization as a source of order beginning to be understood.

Although the concept edge of chaos is widely accepted and referred to, some researchers, such as James Crutchfield, maintain that it is suspect, and that there is not a simple continuum between order and chaos (Johnson, 1996: 285). David Green (1995) on the other hand, in discussing evolution in complex systems suggests that instead of adapting towards an edge, many evolving systems flip-flop backwards and forwards across a 'chaotic edge'.

2.2.3 Self-Organization

Cilliers (1998: 90-93) has attempted to define self-organization and has provided a comprehensive description of the general characteristics and principles of self-organization abstracted from a number of examples quite diverse in nature. Thus, the full set of characteristics will not be found in all complex systems, but the more complex the system the more that will be apparent. Self-organization can work at different levels and according to varying constraints. There is a necessary conformity, to the extent even of an overlap, with the general characteristics of complex systems listed in 2.2.1.

Cilliers has proposed a working definition of self-organization (1998: 90):

> The capacity for self-organization is a property of complex systems which enables
> them to develop or change internal structure spontaneously and adaptively in order
> to cope with, or manipulate, their environment.

It is important to highlight the difference between self-organization and autopoiesis, which is the self-reproduction of a system's network of elements from the very same network of elements (3.8 and 4.1.4). The two terms sometimes seem to be confused and used to refer to the same phenomena, particularly when applied to entities other than living organisms. Depending on the particular circumstances the distinction may or may not be that important.

Cilliers lists eight general characteristics of self-organizing systems, which he refers to as attributes. They are summarized as follows:

26

(i) The structure of the system is not the result of an *a priori* design, nor is it determined directly by external conditions. It is the result of *interaction* between the system and its environment.

(ii) The internal structure of the system can adapt dynamically to changes in the environment, even if those changes are not regular.

(iii) Self-organization is not merely the result of processes like feedback or regulation that can be described linearly. It involves higher-order, non-linear processes that cannot be modelled by sets of linear differential equations.

(iv) Self-organization is an emergent property of a system as a whole. The system's individual components only operate on *local* information and general principles. Complex macroscopic behaviour emerges from local microscopic interactions.

(v) Self-organizing systems increase with complexity over time, 'learning' from experience and 'remembering' previous encountered situation. The more that is remembered, the better able the system is to make better comparisons. This increase in complexity implies a local reversal of entropy and may also partially explain why such systems tend to age. Self-organizing systems are bound by the finite constraints of the physical world. Hence, they inevitably become saturated at some point.

(vi) In light of (v), clearly self-organization is impossible without memory and, therefore, always has a *history*. Previous conditions form vital influences on current behaviour. On the other hand, memory is impossible without some form of selective forgetting, for to pile up information without integration renders it insignificant. Such a process creates memory space, but more importantly, it provides a measure of significance of the stored pattern.

(vii) The self-organizing process is not determined by specific goals; therefore, it is often difficult to talk about its function. When a system is described within in the context of a larger system it is possible to talk of a function *only in that context*. The process of self-organization is the result of an evolutionary process whereby a system will not survive if it cannot adapt to more complex circumstances.

(viii) It is not possible to give crudely reductionistic descriptions of self-organizing systems. Units on the microscopic level do not 'know' about macroscopic effects. As these effects are manifested in collections that do not involve anything besides the microscopic units, the various levels of the system are in principle intertwined and, therefore, cannot be given independent descriptions.

As Cilliers describes it the self-organizing process operates in the following way. Clusters of information from the external environment flow into the system, influencing the interaction of some components or nodes (e.g. Kauffman's lightbulbs) of the system and altering the values of the weights in the network. According to Hebb's rule (1949) the connection strength between two units in a system should increase proportionally to how often it is used. In this way, a network will develop internal structure based on the local information available at each node, which development of structure can also be called learning. Thus, if a certain cluster is presented regularly the system will acquire a stable set of weights that 'represents' that cluster. That is, a certain pattern of activity will be caused in the system each time that specific cluster is present. If two clusters are regularly present together the system will automatically develop an association between the two. For example, if a certain state of affairs regularly causes harm to a system, the system will associate that condition with harm *without having to know beforehand that the condition is harmful.* As the system encounters different conditions in the environment, it will develop new structures to 'represent' those conditions, within the memory constraints of the system (Cilliers, 1998: 93).

For a system to develop in response to conditions in the surrounding environment some interconnections have to terminate in sensors that can sense aspects of the environment and stimulate the system accordingly. An event in the environment will now cause some activity inside the system and this activity can be used to alter the structure of the system, but only by means of information available locally at each node – no global perspective is necessary. Provided the information is not fed into a homogeneous network in a symmetrical manner, the nodes of the system will be activated irregularly. Some will be more active than others. By simply increasing the weights associated with active nodes, decreasing the rest, the pattern of activity will be reinforced. If the external event does not reoccur this pattern will eventually be forgotten or eroded by other patterns. But, if the event is significant, occurring often, the pattern will be continually reinforced, and in this way the system develops a stable structure that enables it to recognize important events through a process of self-organization.

28

The most important aspect of self-organization is the emergence of structure through the activity of microscopic units that are without access to global pattern. Thus, the principles that determine behaviours of weights and nodes locally are very important. Following Von der Malzburg (1987: 272), Cilliers (1998: 94) has identified a number of preconditions for self-organization in complex systems, which I again summarize:

(i) The system consists of a *large number* of microscopic elements or units. Typically, they are relatively undifferentiated initially. (There is no need for pre-defined structure, but it is not excluded).

(ii) The strengths of the interconnections change as a result of *local information* only. These changes are often self-maintaining (positive feedback is involved), and cause the system to move away from the undifferentiated state.

(iii) There is competition among units. Competing for limited resources is the basic driving force behind the development of structure. Stronger units thrive at the expense of others. If resources were limitless no meaningful structure would evolve. Boundaries, limits and constraints are preconditions for structure.

(iv) There is *cooperation* between at least some of the units. If only single units 'won' the resulting structure would be too simple for self-organization to evolve. Cooperation is also necessary to form association among patterns. Mutual reinforcement and cooperation are preconditions for a rich, meaningful structure.

(v) The interactions among units have to be *non-linear*. Small changes must be able to have large effects, and the combination of patterns should result in the formation of new ones, not merely in linear combinations of the constituents.

(vi) An important secondary principle is *symmetry-breaking*. If the initial state of the system is fully homogeneous, the evolving structure could be too symmetrical. This will inhibit the development of complex structure. Symmetry-breaking is usually achieved by means of missing or incorrect connections, as well as by the non-linearity of the system and the resulting sensitivity to small fluctuations.

(vii) Entrainment is another secondary principle. Some patterns will catch others in their wake, in the sense that they will start appearing in concert, and this will increase the order in the system and facilitate the formation of association through resonance.

(viii) Lastly, the most important principle requires that the *memory* in the system be stored in a *distributed fashion*. The connection strengths, or weights, between nodes in a network perform the function of storing information. Since each weight only has access to local levels of activity, it cannot perform the more complex function of standing for a concept. Complex concepts would involve a pattern of activity over several units. The fact that information is distributed over many units not only increases the robustness of the system, but makes the association of different patterns an inherent characteristic of the system – they overlap in principle.

No complex system, whether biological or social, can be understood without considering its history. Two different systems placed in identical conditions will respond in vastly different ways if they have different histories. However, the history of a system is not present in the system in such a way that it can be reconstructed. The 'effects' of the history of the system are important, but it is continuously transformed through the process of self-organization. Only traces of history remain distributed through the system. Global behaviour of the system is the result of 'patterns of traces' (Cilliers, 1998: 107-108). Again, think of Kauffman's lightbulbs.

2.2.4 Self-Organized Criticality

It has been noted that complex systems show a tendency to move to criticality and increased complexity poised at the edge of chaos. But complex systems often display unpredictable behaviour, such as earthquakes, avalanches, sudden biological extinctions and stock market crashes which cannot be explained if the possibility of self-organizing behaviour is ignored.

Poised systems need no huge external force to move massively. This is what Per Bak, working with Chao Tang and Kurt Weisenfeld, termed self-organized criticality:

> ... *many composite systems naturally evolve to a critical state in which a minor event starts a chain reaction that can affect any number of elements in the system. Although composite systems produce more minor events than catastrophes, chain*

reactions of all sizes are integral part of the dynamics. According to the theory, the mechanism that leads to minor events is the same one that leads to major events. Furthermore, composite systems never reach equilibrium but instead evolve from one meta-stable state to the next.

Self-organized criticality is a holistic theory: the global features, such as the relative number of large and small events, do not depend on the microscopic mechanisms. Consequently, the global features of the system cannot be understood by analyzing the parts separately. To our knowledge, self-organized criticality is the only model or mathematical description that has lead to a holistic theory for dynamic systems.

(Bak and Chen, 1991: 26)[6]

To explain the concept they proposed the metaphor of a conical sand pile on a tabletop, with a steady flow of new sand grains being slowly trickled down on to its apex. The sand pile grows higher and higher until a critical height is reached when it grows no more. Old sand cascades down the sides as fast as new sand is added. The pile is self-organized in the sense that it reaches a steady state without any external influences to shape it; and it is in a state of criticality in the sense that sand grains on the surface are barely stable. The microscopic surfaces and edges of the sand grains are interlocked in every possible combination and are just ready to give way. So, when a falling grain next happens there is no certainty as to what might occur. Maybe just a tiny shift in a few grains, maybe a minor slippage of grains down one side, or possibly a catastrophic avalanche ripping away a large section of the pile. It depends on whether or not the critical point has been reached and then exceeded. Once it is reached the effect of a single falling grain is not predictable.

Large avalanches are rare, small shifts are frequent, but the steady stream of falling grains triggers cascades of all sizes, a fact that manifests itself in terms of a 'power law' – the frequency of a given cascade size is inversely proportional to some power of its size (Waldrop, 1992: 305).

Complex systems tune themselves towards optimum sensitivity to external inputs ... at the edge of chaos. The system will attempt to optimize the number of attractors in a stable state (see 2.2.2). A system that only behaves chaotically is useless while a system that is too stable is also

31

handicapped. This is because if each required state of the system has to be represented by a strong stable attractor a large portion of the system's resources are tied up, restricting the capacity of the system for adaptation. Furthermore, movement from one stable state to another will require very strong perturbations. However, at the point of criticality the system will be able to change its state with the minimum amount of effort as the number of stable states will be optimized (Cilliers, 1998: 97).

2.2.5 Adaptation

Complex systems are often referred to as complex <u>adaptive</u> systems and 'usually' complex systems will be complex adaptive systems. This is because 'usually' they are open systems that through the process of self-organization react with their environment (2.2.1, vii). They are able to 'adapt' to changes in the environment, which implies that their internal structure is influenced by external conditions or forces. At one extreme there are well ordered systems with fixed internal structures. These are too cumbersome and slow to adequately adapt to complex situations. At the other extreme there are systems with no independent structure, where the structure is fully determined by the conditions of the environment, mimics it and is incapable of acting in that environment since it will be fully at its mercy.

Living systems have to operate in extraordinarily complex conditions, and their adaptivity is of prime importance for their very survival. Such a complex adaptive system must be able to interpret their environments and to do this two attributes are vital: some form of resistance to change and some method for comparing conditions. These attributes translate into a need for some form of memory so that the system can *learn* to cope with environmental changes (Cilliers, 1998: 99).

One of the fundamental mechanisms of adaptation in any given system is a revision and recombination of its 'building blocks'. Systems thereby evolve, for at some fundamental level the processes of adaptation, learning and evolution are the same. The possibilities for the emergence of system properties, not evident from those of its component parts, are compounded when the elements of a system include some capacity for learning and adaptation (Holland, 1998: 6).

32

A complex adaptive system has many levels of organization with 'agents' at one level may serving as the building blocks for agents at a higher level. Systems within systems exist, an analogy sometimes used being a set of Russian dolls – although each doll is hardly a complex adaptive system. A better illustration would be: a group of proteins, lipids and nucleic acids will form a cell, a group of cells will form a tissue, a collection of tissues an organ, a set of organs an organism and an association of organisms an ecosystem. Complex adaptive systems are constantly revising and rearranging their building blocks as they gain experience of their environments. Succeeding generations of organisms, for example, will rearrange their tissues through the process of evolution (Waldrop, 1992: 145-46).[7]

Jean-Pierre Changeaux and his colleagues (Changeaux et al., 1984) have identified two mechanisms by which a system can respond and adapt to its environment:

(i)   An instructive mechanism where the environment *imposes* order directly on the structure of the system.

(ii)   A *selective (Darwinian)* mechanism where the increase in order is a result of an interaction between the system and the environment. The environment does not *determine* the structure of the system, but influences the development, as well as the transformation, reinforcement and stabilization of patterns in the system.[8]

In organisms natural selection is usually seen as a process of 'pulling' an adapting population towards peaks of high fitness[9] while adaptation can be thought of as a process of 'hill climbing' through minor variations towards such peaks (Kauffman, 1995: 154). Thus, it is the dynamic nature of self-organizing, complex adaptive systems that their structure is continuously transformed and evolves through the interaction of contingent, external factors and historical internal factors.

As a result of the complex patterns of interaction, the behaviour of a complex adaptive system cannot be explained solely in terms of its basic components, despite the fact that such a system does not consist of anything other than these components and their interconnections. They are anti-reductionistic. Complex characteristics emerge through processes of interaction within a system (Cilliers, 1998: 106).

2.2.6 Emergence

John Holland explains the rise of emergent behaviour by describing the structure of a system as continuously transformed by the parallel action and interaction of many 'agents'. The classic description of agent-based emergence is Douglas Hofstadter's (1979) metaphor of the ant colony. Despite the limited repertoire of the individual agents – the ants – the colony is a remarkably complex social system and the colony exhibits amazing flexibility in probing and exploiting its surroundings. The simple 'laws' of the agents generate an emergent behaviour far beyond their individual capacities, the emergent behaviour occurring without direction by a 'central executive' (Holland, 1998: 5).

Emergence usually involves patterns of interaction that persist despite continual turnover in the constituents of the patterns. An example is the standing wave in front of a rock in a white-water river. The water molecules making up the wave change instant by instant, but the wave persists as long as the water flows. Ant colonies, cities and the human body (which turns over all of its constituent atoms in less than two years) offer more complex examples.

Persistent patterns at one level of observation can become the building blocks for persistent patterns at still more complex, or at least more complicated, levels. The subassemblies of a watch, a lever, a wheel and so on – are the building blocks for the mainspring subassembly. That subassembly, when combined with other similarly formed subassemblies, such as the gearing of the hands, form the complicated system of a watch. At each level of observation the persistent combinations of the previous level constrain what emerges at the next level (Holland, 1998: 7), but there is a hierarchy of emergence. As Philip Anderson (1972)[10] has pointed out when discussing our complex universe: at each level of complexity, entirely new properties appear (emerge), and at each stage, new laws, new concepts, and generalizations are necessary.

The subject of emergence is convoluted and as an area of scientific study it is very much in its infancy. Many of the problems that baffle us – from the control of economies to the understanding consciousness – involve emergent phenomena in a crucial way. One might casually infer that this fact somehow signals an impassable barrier and that we have gone as far as science can take us, that problems like emergence will lie forever beyond our ken.

Our ignorance of most aspects of cognition presents a serious deterrent to the understanding of emergence. It may be that the aspects of the universe that we can understand in a scientific sense, that part which we describe via laws, axioms and equations, may constitute a small fragment of the whole of Reality. If so, then there may well be aspects of emergence that we *cannot* understand scientifically. Nevertheless, we already know that there are lawful fragments in which we can explain emergence. But we are far from yet deriving a body of general theorems to link the behaviour of individual agents downward to the interaction of simple mechanisms, while revealing the emergent properties of aggregates of those agents.

Science continues to move on to an ever-broadening perspective. It is the search for theorems that puts the study of emergence squarely in the scientific domain. Although the theoretical scientist proceeds via an amalgam of discipline, modelling, the selective use of observations, and sheer intuition, the end product is a rigorous (unambiguous) derivation of the consequences (theorems) of a set of inferred laws (generators) (Holland, 1998: 231-239).

2.3 Complex Systems Research

Complex systems are encountered in many fields such as economics, biology, sociology and politics. In order to study them, to understand them and to predict and control their behaviour it is necessary to model the complex structures involved.

2.3.1 Modelling Complexity

Symbolic rule based models constitute the classical approach to the modelling of complexity, in terms of which the complex system is reduced to a set of rules that describe the system adequately. The problem lies in finding those rules, assuming they even exist. Thus, are they adequate for complexity research? They can be, but in models of complex systems all the complex characteristics have to be modelled explicitly. High levels of interconnectivity, recurrency and distributedness, for example, have to be algorithmically described. Such approaches often fail in their attempts to reveal the true nature of complexity. Complexity is incompressible. A complex system cannot be reduced to a simple one unless it was simple to start with. Since the model has to be as complex as the system it models, it cannot reveal the 'true nature' of the system in a few logical principles. Complex systems also have special

35

relationships with their environment as far as the manner of processing information and the developing and changing of internal structure are concerned (Cilliers, 1998: 24).

Accordingly, many researchers use connectionist models to study complexity.

2.3.2 Connectionism

Connectionism is a method of information processing derived from an understanding of the brain and central nervous system. Functionally the nervous system consists of richly interconnected cells called *neurons*. When a neuron is sufficiently stimulated it *fires*, producing an electrical impulse that goes out over a long extension of the neuron called the *axon*.

The axon forms contacts, called *synapses, with many other neurons*. When a pulse arrives at these synapses, it stimulates the neuron activated. If enough pulses arrive at the synapses on a neuron's surfaces within a short time interval, the neuron in turn fires and this impulse in turn provides synaptic input to other neurons (Holland, 1998: 20). A neuron uses the sum of its inputs to decide what output to generate. However, each input is first multiplied by a certain 'weight' or value, and this weight determines the connection strength between two specific neurons.

2.3.2.1 Neural Networks

Neurons form part of large networks with complex connection patterns, and since the weights determine the influence of one neuron on another, the weights determine the characteristics of a network. The way in which the neurons are interconnected is also important (Cilliers, 1998: 26-27). The weights have real values that can either be positive (excitatory), negative (inhibitory) or neutral (two respective neurons not connected). The neurons are very simple computational units that calculate the sum of their weighted inputs and pass this value through a non-linear transfer function.
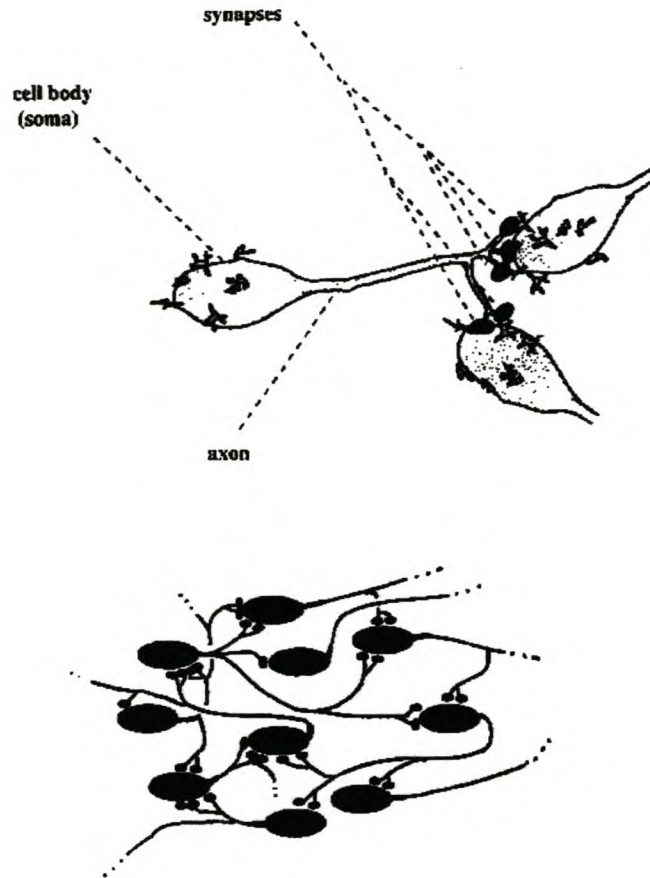
Figure 5.

Neuron and neural net (highly stylized).

Some of the neurons in the network serve as input units that receive information from outside. Similarly, some neurons serve as output units where the result of the network's calculations can be found. In simple network structures, like the multi-layer perceptron the neurons are arranged in layers. In between the input and output layers are additional layers usually called hidden layers. If an input is presented to the network, it will percolate through the network and generate an output. Since the neurons themselves are all essentially similar, the transformation performed by the network is determined by the values of the weights.

The network is basically trained to perform certain tasks by showing it examples, of say a tree and things that can be confused with trees, in terms, say, of a classification process. During the learning phase each presentation is accompanied by the correct output value for that input. The network then automatically adjusts the values of the weights to minimize the discrepancy

37

between the input and the output. These presentations are continued until the network converges on a set of weight values that enables the network to distinguish between the various examples of trees and non-trees. If the training examples were adequate, the network should also be able to generalize its classification to examples of trees it has not seen before (Cilliers, 1998: 67).
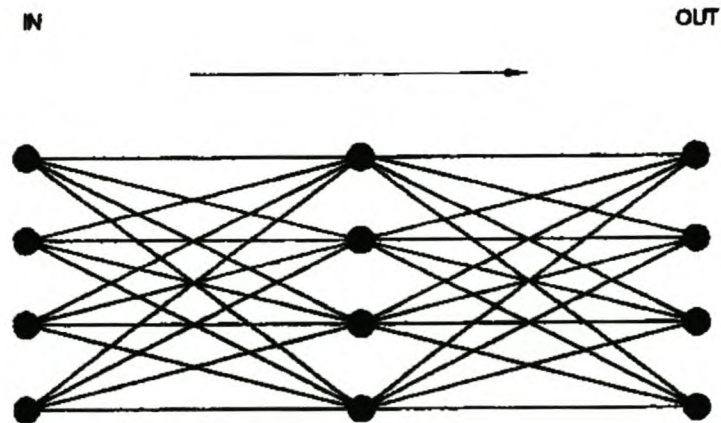
Figure 6.
A simple feedforward neural network.

The power is in the connections not in the neurons, or nodes, in the same way that the essence of life is in the organization of its system and not in the constituent molecules. Often the nodes, the individual agents, in a system can effectively be brainless or dead.

2.3.2.2 Distributed Representation

Three characteristics of neural networks are directly related to their distributedness. The first is that in using networks to solve complex problems it is not necessary to have an explicit theory about the problem, contrary to such a need with conventional computational problem solving. With complex systems it can be extremely difficult, if not impossible to construct such a theory since very many factors can interact in complex, non-linear ways. Under these circumstances theory construction involves large-scale reduction with a high risk of an abstract, inadequate system model. A neural network has no need of a complete and explicit theory since, in effect, it encodes the relationships between the numerous factors in a non-linear, distributed way.

38

From a practical point of view the problem is reduced to finding an appropriate way of presenting the information to the network. Ideally the network must have the same level of complexity as the system itself, which means if the latter is truly complex it will be very difficult to construct and as difficult to analyze as the system itself. A simpler model that reduces complexity may provide a number of useful descriptions of the system, but the implications of using such a model must be carefully considered.

The second important characteristic of distributed networks relates to the ability to generalize solutions. Once trained to perform a specific task they should be capable of dealing with new inputs, allied to, but not identical to the training examples.

Finally, the third characteristic concerns the robustness of this approach. When a specific concept or feature is encoded by a specific neuron, that feature would be lost should the neuron be damaged. However, when the representation is distributed, no specific feature of the network is tied to a specific neuron. Should neurons be damaged, it would only slightly reduce the overall operation of the network. Robustness is vital to a system that has to deal with contingencies of the real world.

Despite its wide use of connectionist models by researchers in complexity, connectionism has received much criticism over the years from certain quarters. A detailed discussion of the pros and cons of connectionism and the problems of representation can be found in chapters 2 and 5 of Paul Cilliers' book *Complexity and Postmodernism*.

In the study of complexity aimed at the development of general theories the neural network most often applied in practice is the multi-layer perceptron trained with the back-propagation algorithm as described above (Cilliers, 1998: 69-70). However, connectionist models did not supply us with the tools for telling us everything we want to know. For example, they cannot explain emergence in economies, societies or ecosystems where the nodes or individual agents are 'smart' and constantly adjust to each other. To understand such systems an understanding of the co-evolutionary interplay of competition and co-operation is required. This will be discussed in 4.3.

2.3.3 Prediction

For any system one of the most important criteria is the ability to predict the behaviour of the system. However, as we are often working with complex systems that cannot be described by means of classical theory, predicting their behaviour can be problematic.

By mapping the major constraints pertaining to a system, and some knowledge about its history and environment predictions can be attempted, but never with any certainty. Hence, any plan of action has to be flexible. If a plan is too rigid, with too much central control, the system will be unable to cope with unpredictable changes. On the other hand it would be impractical, and could be disastrous if the system tried to adjust itself to every superficial change. Being able to discriminate between changes that should be followed and those that should be resisted is vital to the survival of any system, either organization or organism. The optimal situation is when control of the system is not rigid and centralized, but distributed over the system, ensuring that positive dynamics of self-organization is effectively utilized (Cilliers, 1998: 110).

2.3.4 Artificial Intelligence and Artificial Life

In 1950 Alan Turing published his paper *Computing Machines and Intelligence*, sparking off a debate still raging today over the question of 'can machines think'? The paper was notable for its introduction of an operational test, the *Turing Test* for determining whether a machine is thinking in the style of a human being. For fifty years the search for artificial intelligence has gone on, and while to date no computer has convincingly passed the test, for many "Artificial intelligence, in a parallel machine, remains a compelling and discernable prospect" (Churchland & Churchland, 1990:26-31).

Others disagree. Roger Penrose in his 1989 book *The Emperor's New Mind* maintained that the human mind is capable of transcending or going beyond *rational thought,*[11] and hence can never be duplicated in a machine (Casti, 1995: 153). Humans can know things that are not simply the end result of following a simple set of rules. This leads to the whole question of human consciousness, which has been described by Francisco Ayala as "the climax of one kind of progress, that is information processing".[12] Norman Packard agrees. "The idea is a natural. In the evolution of the biosphere you see computation of and information processing happening at different levels and different places. You have information processing within organisms, within

cells of organisms, and within units comprised of many organisms … as in ant colonies and the colonies of other social insects. And of course in human society." Packard believes that evolutionary models he has been working with will eventually develop behaviour rich enough that some kind of consciousness will emerge. In other words, to the point where in the computer model, a form of artificial life, the level of information processing in the system evolves toward what we could call consciousness. Artificial life becoming self-aware (Lewin, 1999: 170-171). The mind boggles.

Artificial life is often traced back to the Hungarian mathematician John von Neumann. Brought to Los Alamos to help solve equations on the hydrogen bomb, working there with his colleague Stanislaw Ulam he developed a mathematical kaleidoscope called a cellular automaton (Johnson, 1996: 254). A cellular automaton consists of a grid of cells that turn on and off, or change colours, according to a set of rules. Like Boolean networks and Kauffman's autocatalytic sets using lightbulb models, cellular automata progress through a series of states, at which each cell examines the activity of its neighbours, and then reacts according to the rules.

Complex dynamic patterns develop and roam across the entire grid, the nature of which is influenced, but not totally determined in detail, according to the activity rules. Global structures emerge from local activity, a characteristic of complex systems (Lewin, 1999: 46-47). The patterns navigate around the checkerboard universe, even cloning themselves, effectively self-reproducing. In the simplest case a cell can be either white or black, on or off, and a typical rule might be that if four or more of a cell's eight contingent cells are white that central cell changes state. The rules can be varied to include a number of colours or states that a cell may have.

The overriding lesson which has caused excitement amongst the so called A-life movement scientists, such as Christopher Langton at the Santa Fe Institute, is that rich, often unpredictable behaviour can emerge from simple local interactions. This is reminiscent of what occurs in a living metabolism. Molecules blindly interact with their neighbours giving rise to a complex system. Neumann proved mathematically that it was possible for a pattern in a cellular automaton to reproduce itself, requiring some 200 000 cells and 27 possible states, but it was left to later computer programmers to design simpler self-reproducing cellular automata. One of Langton's claim to fame is a small loop of cells, shaped like a 'Q' which can extend its tail into unoccupied territory and duplicate itself (Johnson, 1996: 255).

41

In a simulation called TIERRA, developed by ecologist Tom Ray, self-replicating digital organisms hone themselves through random mutation and selection into more efficient forms. An original ancestor, consisting of 80 lines of computer code, is supplanted by simpler self-replicators of seventy-nine lines, then seventy-eight and then seventy-seven. They flourish because they can live on less 'energy', duplicating themselves with fewer cycles of the computer's central processor. These programmes then give way to even smaller versions, but at some point a profound change occurs. The organisms are preyed on by parasites, compact little programmes that, like viruses, have developed the ability to copy themselves using their hosts' replicating machinery. The hosts then develop defenses against the parasites, and an evolutionary battle ensues.

But can such creations be considered 'live'? Psychologist Steven Harnad argues[13] that it is ridiculous to confuse artificial creatures with biological ones. To be real, a simulated creature would have to interact with the environment, and not just a simulated one. For him artificial life may mimic some biological processes, but unless there is some contact with reality it remains no more than a simulation. Or is this being parochial or anthropocentric? Is ours the only universe that counts? Some A-life enthusiasts are so convinced that information is fundamental, that information is real. The argument goes that simulated creatures would have no way of knowing they are simulations. Hence, how do we know that we are not simulations ourselves, running on a computer in another universe? (Johnson, 1996: 256-257).

In Langton's view artificial life is in effect the inverse of conventional biology. Instead of being an effort to understand life by *analysis,* dissecting living communities into species, organisms, tissues, cells, and finally molecules, artificial life is an effort to understand life by *synthesis.* That is, by putting simple pieces together to generate lifelike behaviour in man-made systems. Its credo is that life is not a property of matter per se, but the organization of matter (Waldrop, 1992: 277), thus following connectionist thinking. It leads towards a deeper understanding of how life and consciousness could have emerged in a universe that began with neither (Waldrop, 1992: 292).

The operating principle of artificial life is that the laws of life must be the laws of dynamic form, independent of a particular carbon-based chemistry that happened to arise on the Earth three and a half billion years ago. Its promise is that by exploring other possible biologies in a new medium – computers and robots – artificial life researchers can gain a new understanding of our

own world through a cosmic perspective on what happens in other worlds. We need to view *life-as-we-know-it* in the context of *life-as-it-could-be,* or will be, says Langton (Waldrop, 1992:277).

Could we be the first species to create life? Can we ultimately create our own successors that far surpass us in intelligence and wisdom? These are questions that are being seriously asked. Artificial life is more than just a scientific and technical challenge. It is a challenge to our most fundamental social, moral, philosophical, and religious beliefs.

Artificial life research, using connectionist models, has not as yet explained what makes life and consciousness possible. It is not enough to say 'emergence' since the cosmos is full of emergent structures like galaxies, clouds and snowflakes that have no independent life. Something more is required, and this is why the concept of the 'edge of chaos' is very compelling to many complexity scientists, for the missing 'something' appears to be a certain balance between the forces of order and disorder. What is important is to examine not how a system is made but how it behaves, for what one finds, according to Langton, are the two extremes of order and chaos. The abstract transition phase between the two, the edge of chaos, is where complex behaviour occurs. An analogy is the difference between solids, where the atoms are locked in place, and fluids where they tumble randomly. As a solid is heated, for example, complex behaviour results when the melting temperature is reached and the material changes physical form without any change in chemistry.

Complex systems are both stable enough to store information, yet evanescent enough to transmit it. These are the systems that can be organized to perform complex computations, to react to the world, to be spontaneous, adaptive, and even are, or could be alive.

Langton demonstrated the connection between complexity and phase transitions in cellular automata while we will recall that Kauffman discovered the same thing with his autocatalytic lightbulb models when he found that if the connections in his networks were too sparse the network froze, too dense and they churned chaotically. Only in between, when there were two inputs per node, did the networks produce the stable state cycles he was searching for (Waldrop, 1992: 292-293).

But does this phenomena hold true for the real world?

43

CHAPTER THREE

THE EARTH AS A COMPLEX ADAPTIVE SYSTEM

3.1 Introduction

Space exploration has given us the opportunity to view the Earth from a distance. It is seen as a marvellous blue and white planet suspended in the vast cosmic chain. The words of the astronauts who have been privileged to contemplate the Earth from afar are testimonies to the grandeur, majesty, rationality and beauty of the cosmos and everything in it, not least our living Earth.

> *The Earth reminds me of a Christmas tree suspended against the black depths of the universe. The further away we go, the smaller it gets, until finally it is reduced to the most beautiful imaginable little ball. That living object, so beautiful and so warm, looks frail and delicate.*
>
> *James Irwin[14]*

> *When I was the last man to walk on the moon in December 1972, I stood in the blue darkness and looked in awe at the earth from the lunar surface. What I saw was almost too beautiful to grasp. There was too much logic, too much purpose – it was just too beautiful to have happened by accident.*
>
> *Gene Ceman[15]*

And it was another astronaut, Joseph Allen who intuitively observed:

> *With all the arguments, pro and con, for going to the moon, no one suggested that we should do it to look at the Earth. But that may in fact be the most important reason.[16]*

44

Thus, when human beings have seen the Earth from beyond it they have come to understand that they and the Earth are a unit, that this unit belongs to a larger unity, our galaxy, and ultimately the whole complex system of the universe itself (Boff, 1997: 200-201).

What is pertinent is not only the 'systems within systems' concept but the observation that the Earth, humankind and all living things make up a *single entity*. The idea is not that a unity derives from a set of relationships, but that as constituent parts we make up a single entity that is complex, diverse, contradictory, and endowed with enormous dynamism (Boff, 1997: 14). A single complex system that, following James Lovelock, many now refer to as Gaia. Human beings are not just *on* the Earth. We are the sons and daughters of the Earth, the Earth itself in its ultimate expression, so far, of consciousness (Capra, 1992).

This perception of organic unity and mutual belonging is becoming crystal clear as complexity research and modern Darwinian biology come together to form a coherent picture. Our destiny is inseparably connected to the fate of the Earth and the whole cosmos of which the Earth is a part.

Life has emerged out of an evolutionary process, from energies and particles at the very outset, by way of a primordial gas, the supernovas, galaxies, stars, the geosphere, the hydrospere, the atmosphere and finally the biosphere containing Earth's life systems. Life with all its complexity, self-organization, adaptation, emergence, connectedness and self-transcendence, results from the potentialities of the universe itself.

Ilya Prigogine (1977, 1984) studied how thermodynamics works in living systems. They always appear as open systems and therefore have a fragile equilibrium and are always adapting to their environment. They are continually exchanging energy with the environment. They consume a great deal of energy, and hence they increase entropy (expenditure of useable energy). Prigogine calls them 'dissipative structures' (energy spending). But they are also dissipative structures in a second paradoxical sense, since they dissipate entropy. They metabolize the disorder and chaos in the environment into order and complex structures that become self-organized, escaping entropy. In other words they produce negentropy – negative entropy – or put positively, they produce syntropy. For example, the sun's photons are useless to the sun, simply energy that escapes when the hydrogen from which it is sourced breaks up. These photons, which are disorder, serve as food for plants in their process of photosynthesis.

Under sunlight plants, through photosynthesis, decompose carbon dioxide, which is food for them, and give off oxygen, which is necessary for animal and human life.

What is disorder for one serves as order for another and it is through a precarious balance between order and disorder that life is maintained. Order entails creating more complexity and a higher level of order with less energy dissipation and lower entropy. Syntropy prevails over entropy. In this way the Earth continually evolves towards ever more complex life forms (Boff, 1997: 14-15).

3.2 The Gaia Hypothesis

In 1968 in Princeton, New Jersey, James Lovelock first put forward his Gaia hypothesis at a scientific meeting on the origins of life on Earth. Then in 1979 in his inspirational and classic book *Gaia, A New Look at Life on Earth* (reissued 2000) he explained it in some detail, proposing that the evolution of life and the evolution of the Earth is a single, tightly coupled process, from which self-regulation of the environment emerges. It is not contrary to Darwin's theory of evolution by natural selection but a development of it and an adjunct to it. Lovelock defines Gaia as "a complex entity involving the Earth's biosphere, atmosphere, oceans, and soil; the totality constituting a feedback or cybernetic system which seeks an optimal physical and chemical environment for life on this planet" (2000: 10). Surprisingly, in his books Lovelock makes no reference to the philosophy of Friedrich Schelling as expounded in his major work *Naturphilosophie,* or *Ideas for a Philosophy of Nature* (1797). Schelling's proposed that the whole of reality can be viewed as one single developing organism. Further, that the most significant steps in the process have been, first, the emergence of organic out of inorganic nature, and then, within organic nature, the emergence of man. His thinking was very similar to Lovelock's own hypothesis. *Naturphilosophie* was written twelve years before Darwin was born.

Although a distinguished scientist himself, Lovelock's book has come in for much scientific criticism, probably because it is written as a story in which he gave poetry and myth their place alongside science. In the preface to the first edition he warned: "Occasionally it is difficult, without excessive circumlocution, to avoid talking of Gaia as if she were known to be sentient. This is meant no more seriously than is the appellation 'she' when given to a ship by those who sail in her, as a recognition that even pieces of wood and metal when specifically designed and assembled may achieve a composite identity with its own characteristic signature, as distinct

from being the mere sum of the parts." Unfortunately, as he has said, "My disclaimer was about as much use as is the health warning on a packet of cigarettes to a nicotine addict" (Lovelock, 2000: x).

Today most scientists appear to accept the merits of the hypothesis that in effect the Earth is a kind of living super organism, even though many still balk at the appellation *'Gaia'*. They prefer to talk of Earth system science, or geophysiology. Whatever one's preference, "if Gaia exists the relationship between her and man, a dominant animal species in the complex living system, and the possibly shifting balance of power between them, are questions of obvious importance. The Gaia hypothesis is for those who like to walk or simply stand and stare, to wonder about the consequences of our own presence here. It is an alternative to that pessimistic view which sees nature as a primitive force to be subdued and conquered. It is also an alternative to that equally depressing picture of our planet as a demented spaceship, forever travelling, driverless and purposeless, around an inner circle of the sun" (Lovelock, 2000: 11).

In the 1960s Lovelock was employed by NASA (U.S. National Aeronautics Space Administration) on its planetary exploration programme with the task of developing models for detecting of life on other planets. His starting point was the hypothesis that if there was life on other planets in our solar system it would use the atmosphere and any oceans which might exist as storehouses, and as a means of transporting the materials needed for its metabolism. Such a function would change the chemical balance of the atmosphere in such a way that an atmosphere where life was well established would be appreciably different from one without it. He compared the atmosphere of Earth with those of its neighbours, Venus and Mars, by analyzing the radiation coming from those planets. The results were surprising, for they demonstrated an astonishing supply of the elements beneficial for life, as we know it, in the Earth's atmosphere, in contrast to the atmospheres on Venus and Mars which render life impossible.

On Venus carbon dioxide measures around 96.5% and on Mars 98%, while on Earth it reaches only 0.03%. Oxygen is totally missing from Venus and Mars while on Earth it is about 21%. Nitrogen on Earth is about 79%, but only 3.5% on Venus and 2.7% on Mars. Lovelock drew attention to the fine balance between the chemical and physical elements —the temperature of the Earth's crust, the atmosphere, rocks and oceans, all of which under the effect of light from the sun – render the earth eminently suitable for living organisms under relatively steady state

conditions. The fine balance of this complex system, Gaia, is a result of its own self-organization in which its living organisms are influential.

The concentration of gasses in the atmosphere is apportioned in a way that is optimal for life. Small deviations would mean irreparable catastrophes. For example, the oxygen level in the atmosphere has remained at around 21% for hundreds of million years. Should it rise to 23% it is forecast that fires would ravage the Earth. Likewise if the salt content of the oceans, at around 3.4%, rose to 6% life in the oceans would become impossible, as in the Dead Sea. Similarly the average surface temperature of the Earth has been maintained in a range optimal for living organisms of between 15 and 35 degrees centigrade, even though the solar heat is calculated to have increased by 30% to 50% since life began 3.5 billion years ago. The Gaia hypothesis holds that life and its environment are intrinsically interconnected and thus have been and are evolving in tandem.

Not recognizing a planetary control mechanism, for a long time many critics of the Gaia hypothesis branded it as teleological and, therefore, dismissed it. "Teleological explanations, in academe, are a sin against the holy-spirit of scientific rationality; they deny the objectivity of Nature" (Lovelock, 1995: 32). But the Earth is indeed the best of all worlds for those adapted to it. Geochemical evidence shows that the Earth's crust, oceans, and air are either directly the product of living things or else massively modified by their presence. The oxygen and nitrogen of the air come directly from plants and microorganisms, while the chalk and limestone rocks are the shells of living things once floating in the sea. Life has not adapted to an inert world determined by the dead hand of chemistry and physics. We live in a world that has been built by our ancestors, ancient and modern, a world that is continuously maintained by all things living today.

Organisms are adapting in a world whose material state is determined by the activities of their neighbours. In other words a continually changing environment is a part of the game. Ultimately it is all one complex adaptive system. The activity of single organisms interrelating and acting together changes the material environment to a more stable and yet more complex state. If as a consequence it leaves more progeny, then both the species and the change will increase until a new stable state is reached. On a local scale adaptation is a means by which organisms can come to terms with unfavourable environments but on a planetary scale, according to Lovelock,

"the coupling is so tight that the tautologous notion of 'adaptation' is squeezed from existence. The evolution of the rocks and the air and the evolution of the biota are not to be separated" (1995: 33).

But does the assumption of the close coupling of life and its environment change the nature of the whole system? Is homeostasis, the ability of a system to maintain stability by keeping its parameters within certain limits, a reasonable prediction of the Gaia hypothesis? The difficulty in answering these questions comes from the sheer complexity of the biota (the totality of living things) and the environment, and their interconnectedness in multiple ways in a single system. There is hardly an aspect of their interaction that one can confidently describe by mathematical equation. Therefore, a drastically simplified model was needed, even though Lovelock was conscious of the dangers of reducing the complexity of life to a simple scheme. The model had to be enlightening without being distorting. His answer was his Daisyworld model that he published with mathematician Andrew Watson in *Tellus* in 1983 in a paper entitled *The Parable of Daisyworld*. The model, which was numerically simulated to run on a personal computer, is described by Lovelock as follows (1995: 34-40).

He asks us to envisage a planet, somewhat like the Earth, which he called Daisyworld because the principal plant species are daisies of different shades in colour. Some are dark, some are light and others are neutral in between. The star that lights and warms the planet shares with our Sun the property of increasing its luminosity and heat output over time; apparently a property of all stars. Daisyworld is simplified such that the environment is reduced to a single variable, temperature, and the biota to a single plant species, daisies. Below 5^0 C they will not grow, they thrive at about 20° C and wilt and die at over 40° C. The mean surface temperature of the planet is the balance between the heat received from the star and the heat lost to space in the form of infrared radiation. Daisyworld is assumed to have a constant amount of carbon dioxide, enough for the daisies, but not so much as to affect the climate. Similarly there are no clouds to complicate the model and it is assumed that all rain falls at night. The mean temperature of Daisyworld is, therefore, a function of the average shade colour of the planet, that is, its albedo. If the planet is dark, with low albedo, it absorbs heat and the surface is warmed. If it is light in colour, like snow, about 75 percent of the sunlight is reflected back to space.

Lovelock then asks us to imagine a time in the distant past of Daisyworld. The star that warms it was less luminous, so that only in the equatorial region was ground temperature warm enough for growth, 5° C. The assumption is that the first crop of Daisies is multicoloured, light and dark daisies being equally represented. However, the greater absorption of sunlight in the localities where they grew would have warmed them above 5° C. The light coloured daisies would be at a disadvantage. Their white flowers would have faded and died because, reflecting the sunlight as they would, would have cooled them below the critical temperature of 5° C.
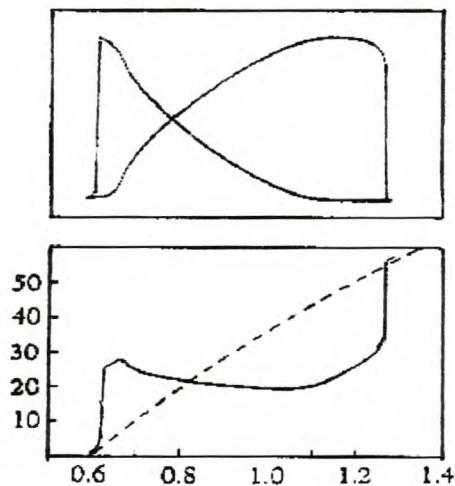
Figure 7.

Evolution of Daisyworld according to geophysiology. The upper panel illustrates daisy populations in arbitrary units; the lower panel temperature in degrees Celcius. The dashed line in the lower panel shows how the temperature would rise in a lifeless Daisyworld.

The next season would see the dark daisies with an advantage, as their seeds would be the most abundant. Soon their presence would not just warm the plants themselves, but, as they grew and spread the temperature of the soil and air, at first locally and then regionally, would also rise. With this rise of temperature, the rate of growth, the length of the warm season, and the spread of the dark daisies would all exert positive feedback and lead to the colonization of

most of the planet by dark daisies. However, eventually the spread would be limited by a rise of global temperature to levels above the optimum for growth. Further spread would lead to a decline in seed production. Also at the higher temperatures white daisies would grow more readily in competition with the dark ones because of their natural ability to keep cool. As Daisyworld's star grew older and hotter the proportion of dark to light daisies would decline until finally the temperature was so great, above the critical 40° C, that all daisies die and the planet again becomes barren.

In Daisyworld, one property of the global environment, temperature, was shown to be regulated effectively, over a wide range of solar luminosity, by an imaginary biota without invoking foresight or planning. Lovelock designed the model, not because he believed that dark or light coloured plants regulate the Earth's temperature by changing the balance between the heat received from the Sun and lost to space, but to rebut the criticism that the Gaia hypothesis was teleological. So far the model remains unchallenged. Thus, if the real world is self-regulating in the manner of Daisyworld, as Lovelock suggests it is, and if climate and environment are a result of an automatic, but not purposeful or goal seeking system, then Gaia is the largest manifestation of 'life' known to us humans. He proposes that the tightly coupled system of life and its environment, Gaia, is made up of at least four components:

i)   Living organisms that grow vigorously, exploiting any environmental opportunities that arise.

ii)   Organisms that are subject to Darwinian rules of natural selection: survival of the fittest.

iii)   Organisms that affect their physical and chemical environment. Animals do so by breathing in oxygen and exhaling carbon dioxide. Plants and algae do the reverse. In numerous other ways all forms of life continuously modify both the physical and chemical environment.

iv)   The existence of constraints on life. For example, it can be too hot or too cold, or too acid or too alkaline. Almost all chemicals have concentration ranges tolerated or needed by living organisms. Pure water will support very little, but neither will the saturated brine of the Dead Sea.

Accordingly, one can argue that life is an open system but exists within a set of boundaries. The outer boundary is the Earth's atmospheric edge to space. Then within this planetary boundary, entities diminish but grow more intense as the inward progression goes from Gaia to ecosystems, to plants, to animals, to cells and to DNA. According to Lovelock there is no clear distinction between living and non-living matter, but rather a hierarchy of intensity going from the 'material' environment of rocks and atmosphere to the living cells.

Before life existed, the solid Earth, the atmosphere and the oceans evolved according to the laws of physics and chemistry alone, careering downhill to a lifeless steady state of a planet almost at equilibrium. Then, at some stage it became favourable for life. Life emerged and the newly formed cells grew until their presence so affected the Earth's environment as to halt the headlong dive to equilibrium. The living organisms, the rocks, the air and the seas merged to form the superorganism, Gaia. But how did life form?

3.3 The Origin of Life

We may never know the sequence of events that lead to the first self-replicating, evolving molecular system to blossom about 3.5 billion years ago. Nevertheless, we can develop theories and models to show how life might realistically have sprung from some primordial soup. DNA (dioxyribonucleic acid), heralded as the master molecule of present life, became a candidate for the first living molecule, but 'nude' DNA does not self-replicate. A complex assemblage of protein enzymes must first be in place. RNA (ribonucleic acid), central to the functioning of a cell, was then considered and is still believed by many biologists to be the starter for life, but efforts to get RNA strands to copy themselves in a test tube have all failed. RNA molecules also appear to need the presence of catalytic protein enzymes. In any event, Kauffman (1995: 42) maintains that there is an insurmountable problem with this hypothesis, namely, that all living things seem to have a minimum complexity below which it is impossible to go. The simplest free-living cells are pleuromona, a very simplified kind of bacteria with anywhere between a few hundred and a thousand genes, and yet RNA can offer no convincing explanation of the observed minimum complexity of all living cells. Kauffman (1995: 43) believes that this threshold is not an accident of variation and selection but is inherent to the very nature of life.

Because there is no satisfactory explanation of how a collection of molecules came together in the right way to form a living cell George Wald in an article in *Scientific American* in 1954, suggested that time is the missing clue. Eventually over billions of years the unthinkably improbable becomes virtually assured. However, this has been widely criticized. In his book *Origins,* Robert Shapiro (1986) calculates that there could conceivably have been 2.5×10^{51} chance attempts at life. But what is the chance of success per trial? Shapiro begins with an argument by astronomers Sir Fred Hoyle and N. C. Wickremasinghe who estimated that to duplicate a bacterium the odds would be 1 in $10^{40\,000}$. So, if the possible number of trials was 2.5×10^{51} at odds of 1 in $10^{40\,000}$ then as Hoyle has stated the idea of life arising from randomness is so incredible that he compared it to the chances of a tornado sweeping through a junkyard and assembling a 747 from the materials in it (Johnson, 1996: 218). Hoyle looked to outer space for the source of life on Earth. Creationists look to a caring, cognizant God. Kauffman (1995: 45) on the other hand believes that what Hoyle and many others have overlooked is the power of self-organization. He holds that whenever a collection of chemicals contains enough different kinds of molecules a metabolism will crystallize from the broth. The metabolic networks need not be build up one component at a time; they can spring up full-grown from the primordial soup.[17] This is Kauffman's previously referred to 'order for free' (2.2.2).

In Chapter 3, *We the Expected* in his book *At Home in the Universe*, Kauffman argues, persuasively for me, that life is a natural product of complex chemical systems. When the number of different kinds of molecules in a chemical soup passes a certain threshold, a self-sustaining network of reactions – an autocatalytic metabolism – will suddenly appear. Life, at its root, lies in the property of *catalytic closure* among a collection of molecular species. Alone, each is dead, but jointly, when catalytic closure is achieved the collective system of molecules is alive. He suggests that life emerged, not simple but complex and whole in the achievement of collective catalytic closure. However, he adds the caveat that to such questions as: "Do we know that such a view is at least theoretically coherent? Do we know it to be physically and chemically possible? Is there evidence for such a view? Is evidence attainable?" the most that can be said is that careful theoretical work strongly supports the possibility, appearing to be consistent with what we know about complex chemical systems. Developments in molecular biology even make it possible to imagine actually creating such self-reproducing molecular systems – synthesized life – within a decade or two (Kauffman, 1995: 48).

A living organism is a chemical system that has the ability to catalyze its own reproduction. A collective autocatalytic system is one in which the molecules speed up the very reactions by which they themselves are formed. Now imagine a whole network of these self-propelling loops. Given a supply of "food" molecules (As and Bs), the network will be able to constantly re-create itself. Like the metabolic networks that inhabit every living cell, it will be alive. The hypothesis is that when a sufficiently diverse mix of molecules accumulates the chance that an autocatalytic system will develop becomes a near certainty. If so, then the emergence of life may have been much easier than we have supposed.
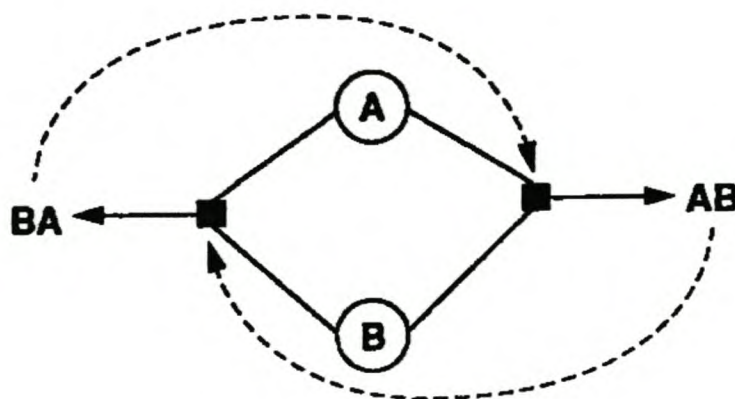
Figure 8.
A simple autocatalytic set.

Two molecules, AB and BA, are formed from two simple monomers, A and B.
Since AB and BA catalyse the very reactions that joins A and B to make the molecules
AB and BA, the network is autocatylitic. Given a supply of "food" molecules (As and Bs)
it will sustain itself.

However, catalysts alone are not sufficient for life. All living systems 'eat'. That is, they take in matter and energy in order to reproduce themselves. They are open thermodynamic systems, about which remarkably little is understood in contrast to closed thermodynamic systems that take in no matter or energy from their environment. The vast flowering of all life forms over the past 3.5 billion years is merely a hint of the possible behaviours of open dynamic systems. So too is cosmogenesis itself, for the evolving universe since the Big Bang has yielded the formation of galactic structures on enormous scales. Those stellar structures and the nuclear

processes within stars, which have generated the atoms and molecules from which life arose, are open systems, driven by non-equilibrium processes in the unfolding universe. We are all complex atoms, living cells, planets, spiral galaxies, the lion and us humans – the logical progeny of that creative power.

A human cell co-ordinates the behaviours of about 100 000 different kinds of molecules as matter and energy cross its boundaries, so to think that understanding a very simple open dynamic system can take us far toward understanding the cell is hubris. But such understanding is at least a start, for even simple non-equilibrium chemical systems can form remarkably complex patterns of chemical concentrations varying in time and space. They are Ilya Prigogine's dissipative systems (3.1) as they persistently dissipate matter and energy so as to maintain their structures. The cell is not only an open chemical system, but also a collectively autocatalytic system. Not only do chemical patterns arise in cells, but cells sustain themselves as reproducing entities that are capable of Darwinian evolution (Kauffman, 1995: 49-54). But by what laws and what deep principles might autocatalytic systems have emerged on the primal Earth?

3.3.1 A Chemical Creation Myth

The crystallization of connected webs can be illustrated by means of 'random graphs', a set of dots, or nodes, connected at random by a set of lines, or edges.

Imagine that the nodes are 'buttons' and the lines 'threads', and that there are 10 000 of them. Randomly choose two buttons and connect them with a thread and then repeat this exercise many times. After a while you will find that you will in all likelihood pick up a button that has already been connected to another so that as a thread is tied between these last two chosen buttons three buttons will now be joined. Eventually, as you continue to choose random pairs to connect, the buttons start to become interconnected in large clusters (Fig. 9, limited to 20 buttons).

The important feature of random graphs is that they show very regular statistical behaviour as one tunes the ratio of threads to buttons. In particular, a *phase transition* occurs when the ratio passes 0.5.

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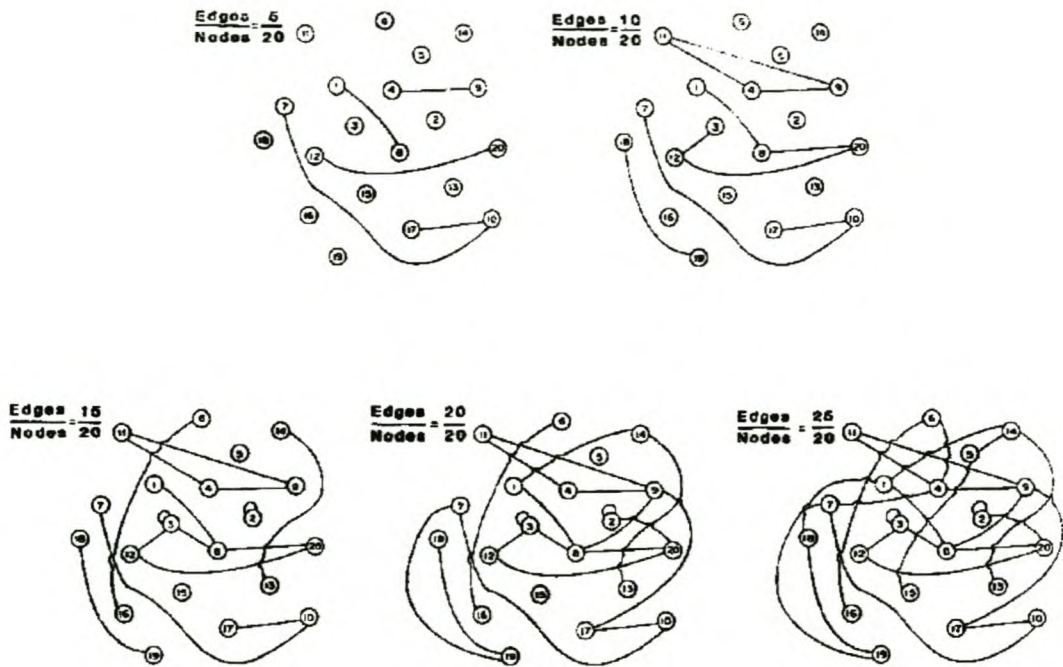
Figure 9.

Crystallization of connected webs.

At that point a 'giant cluster' suddenly forms. As the ratio increases so does the size of the clusters, for, as clusters get larger, they begin to become cross-connected. When the giant cluster forms most of the nodes are interconnected directly or indirectly. In a 10 000 button set, if you pick up one button the chances are that you will pick up possibly as many as 8 000 of the buttons. Once past the 0.5 ratio mark more and more of the buttons and smaller cluster are joined into the giant component but the rate of growth of this component will slow as the remaining number of isolated buttons and small clusters decreases. Figure 10 shows qualitatively the size of the largest cluster among 400 nodes as the ratio of edges to nodes increases. This is a model of what Kauffman (1995: 57) believes led to the origin of life.

The curve is sigmoidal. The sigmoidal curve rises steeply when the ratio of edges to nodes passes 0.5 and the steepness of the curve at the critical ratio depends on the number of nodes

56

in the system, the more nodes the steeper it will be. Were there an infinite number of nodes the size of the largest cluster would jump discontinuously from tiny to enormous, rather like separate water molecules suddenly freezing into a block of ice.
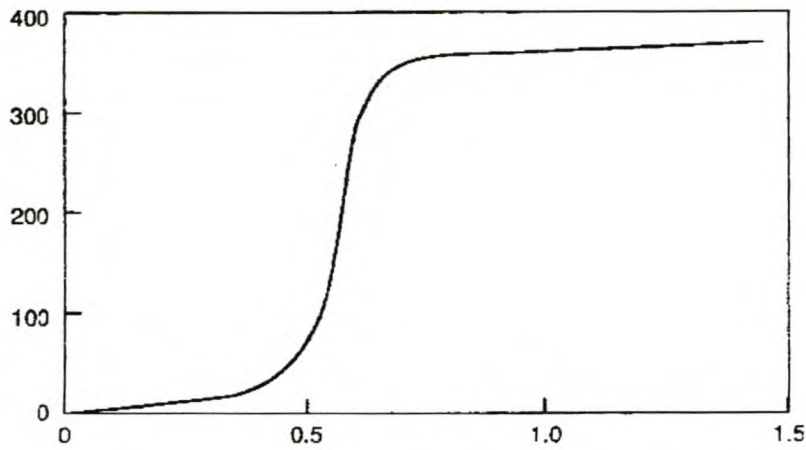
Threads (edges)/Buttons (nodes).

Figure 10.

A phase transition occurs when the ratio of threads to buttons in a random graph passes 0.5 and a giant component crystallizes.

Emergence is a natural, expected property of a random graph. The analogue in the origin-of-life theory will be that when a large enough number of reactions are catalyzed in a chemical reaction system, a vast web of catalyzed reactions will suddenly crystallize at a phase transition. Such a web is almost certainly autocatalytic, self-sustaining and alive (Kauffman, 1995: 54-58).

This theory of life's origins is rooted in an unrepentant holism, born of mathematical necessity. A critical diversity of molecular species is necessary for life to crystallize, emerging whole not piecemeal. We have a hope of explaining why living creatures seem to have a minimal complexity. The concept of catalytic closure will, Kauffman believes, start to appear as a deep feature of the laws of complexity, reemerging in our understanding of ecosystems, economic systems and cultural systems. Catalytic closure ensures that the whole exists by means of the parts, and the parts are present both because of and in order to sustain the whole. Autocatalytic sets exhibit the emergence of holism. If life began with collectively autocatylitic sets they

deserve awed respect, for the flowering of the biosphere rests on the creative power they have unleashed on Earth. If this theory is true and life is more probable than we have supposed we are far more likely to be sharing the universe with life elsewhere (Kauffman, 1995: 69).

3.4 Evolution

One of the most awesome aspects of biological order is ontogeny, the development of an adult organism, such as a fully-grown human being, from a fertilized egg, or zygote. The zygote undergoes about 50 cell divisions to create around 1 quadrillion (10^{15}) cells that form the new born infant. The single cell type of the zygote differentiates to form approximately 260 cell types of the adult – liver cells, nerve cells, muscle cells, and so forth. The genetic instructions controlling development lie in the DNA in the nucleus of each cell, and this genetic system harbours around 100 000 different genes. The many genes and their products are active at the same time and this genomic system can be thought of as a parallel processing chemical complex.

The network in each cell has evolved over some 1 billion years, but according to Kauffman it is not merely 'chance caught on the wing', a result of Darwinian natural selection as Jacques Monod suggested in his book *Chance and Necessity* (1971). Rather it is a spontaneous, natural expression of the self-organization that abounds in very complex regulatory networks. He proposes that we must re-think evolutionary theory to include both selection and self-organization. In due course he thinks we may begin to frame possible universal laws governing this proposed union (Kauffman, 1995: 24:26).

But how would such laws of emergent order, if they should some day be found, be reconciled with the random mutations and opportunistic selections of Darwinism? How can life be contingent, and unpredictable while obeying general laws? It is our quest as humans to understand the emergence of this ordered complexity around us, in the living forms we see, the ecosystems they construct, the social systems that abound from insects to primates and the economic systems by which we live our daily lives. From whence has evolved all this complexity and activity? Ultimately it must be a natural expression of a universe that is not in equilibrium, a system sustained by the persistent dissipation of matter and energy generating order. All free-living systems are non-equilibrium systems, and indeed Gaia and the biosphere are non-equilibrium systems driven by the flux of solar radiation.

It would be of the greatest importance should it eventually be possible to develop general laws predicting their behaviour; but will they ever be? Three principal difficulties will first have to be overcome. Firstly, quantum theory precludes detail prediction of molecular phenomena. Secondly, chaos theory shows that small changes in initial conditions can lead to profound effects. Finally, non-equilibrium systems can be thought of as a computer carrying out algorithms. For vast classes of such algorithms, no compact, law like description of their behaviour is possible since the algorithm itself is its own shortest description. It is incompressible, for there exists no shorter means of predicting what it will do other than to simply execute it and observe the succession of action states as they unfold. Therefore if the origin and the evolution of life is like an incompressible computer algorithm, then, in principle, we can have no compact theory that will accurately predict the details of the unfolding. We must instead simply stand back and watch the pageant.

However, even if evolution is such an incompressible process we are not precluded from the possibility that many features of organisms, and their evolution, are such that laws governing the emergence of life and the population of the biosphere may be discovered that are sufficient to explain evolving phenomena; even if they do not enable us to make detailed predictions. Put another way. We can never hope to predict the exact branchings of the tree of life, but we can aspire to the uncovering of powerful laws that predict and explain their general shape (Kauffman, 1995: 21:23).

3.5 The Natural History of Life

The earliest signs of life on Earth were present 3.45 billion years ago, about 300 million years after the Earth's crust evolved sufficiently to support liquid water, or so it is thought. What experts believe are fossils of well-formed cells are present in the Archean rocks of that period. Single-celled life forms persisted alone in the biosphere for about 3 billion years. Then, about 550 million years ago at the beginning of the Cambrian era, there was a burst of evolutionary activity that generated most of the phyla that exist today. It is estimated that in the Cambrian as many as 100 phyla existed, most of which rapidly became extinct, compared to 32 that exist today. (The vertebrates, our own lineage, arose about 50 million years later in early Ordovician times).

In the Cambrian the higher taxonomic groups filled in from the top down: species that founded phyla formed first. So the early pattern in the Cambrian shows explosive differences among the species that branched early and successively less dramatic variation in later branchings.

Some 245 million years ago, at the end of the Permian, about 96% of all species became extinct, but members of all phyla survived. The vast rebound of diversity that followed, when many new genera and families evolved, but no new classes or phyla, the progression that unfolded was very different than that of the Cambrian. The higher taxa filled in from the bottom up. Why this profound difference? In both cases the greatest diversification came first. Biologists believe the development from a fertilized egg to an adult is a process akin to cathedral building. The foundations have to be right, or else. Thus, there is a view that mutation affects early development much more than later development. Or, put another way, mutants affecting early development are adapting on a more rugged fitness landscape (2.2.5) than mutants affecting late development. Early developments tend become 'locked in'. Therefore, contrary to the Cambrian, by the time of the Permian 300 million years later, early development in the organisms of most phyla and classes was already well locked in. Thus, even when 96% of species became extinct, because of the survival of the phyla, only traits that were more minor were affected by mutation and hence further evolutionary development. Therefore, the top down Cambrian development and the bottom up Permian evolution appears to be a natural consequence of the different structure of their fitness landscapes.

The fossil record shows that over the past 550 million years a great variety of life forms have emerged and then gradually disappeared. The emergence of new species (speciation) and the extinction of others seem to be related, reflecting the spontaneous dynamics of communities in the struggle for survival as species compete with co-evolutionary partners and adapt to changes that arise as a consequence.

The greatest rate of both speciation and extinction occurred in the Cambrian. Over the next 100 million years, the diversity of species apparently stabilized somewhat, but was nevertheless still perturbed by both large and small avalanches of extinction wiping out huge numbers of species. This pattern has persisted to the present day. Whilst some extinctions have a competitive, co-evolutionary explanation, others are attributable to environmental changes, such as atmospheric temperature changes or natural catastrophes. For example, volcanic activity or the meteor

60

impact that is believed to have caused the extinction of the dinosaurs at the end of the Cretaceous period.

Putting aside the phenomena of environmental and natural catastrophic extinctions, the patterns of speciation and extinction seem to be caused, Kauffman proposes (1995: 15), "by internal processes, endogenous and natural ... avalanching across ecosystems and time, are somehow self-organized, somehow collective emergent phenomena, somehow natural expressions of the laws of complexity." In other words, self-organized criticality (2.2.4). He goes on to suggest that these small and large avalanches of creativity and destruction in the natural history of life over the last 550 million years is echoed in systems at all levels, from ecosystems to economic systems, undergoing technological evolution, and to evolving phenomena in our cultural systems and social life as human beings. He suspects that the fate of all complex adaptive systems in the biosphere – from single cells to economies – is to evolve to a natural state between order and chaos, in a compromise between structure and surprise. At this poised state, small and large avalanches of co-evolutionary change propagating through the system as a consequence of the small, best choices of individual agents, competing and co-operating in the fight for survival. He sees humankind, as have and do other species, doing the best it can but eventually becoming extinct, by some unanticipated consequences of our own best efforts.

I concur with this view; and if we do not cease our relentless destruction of our environment our time on this planet will be extremely brief, especially in comparison with the 150 million-year reign of the dinosaurs.

3.6 Coevolution

Any given organisms ability to survive and reproduce depends on what niche it is filling, what other organisms are around, what resources it can gather, even what its past history has been. Organisms in an ecosystem do not just evolve. They coevolve continually, cooperating and competing in a complex dance of co-evolution producing results that are far from chaotic. Species live in the niches afforded by other species, jostling for position next to one another as symbiotic, cooperating mutualists or competitors, predators or prey, hosts or parasites. It has produced a myriad of creatures that are adapted to each other and their environment, often quite exquisitely. For example, flowers that evolved to be fertilized by bees and bees that evolved to live off the nectar of flowers. Coevolution between predator and prey, such as

cheetahs that have evolved to chase down springbok and springbok to escape cheetahs, is often referred to as an 'arms race' or the 'Red Queen Effect'.[18] In a coevolutionary arms race, when the Red Queen dominates, all species keep changing their genotypes indefinitely in a never-ending race just to maintain their fitness level (Kauffman, 1995: 217).

Coevolutionary alliances, rivalries and relationships are found in the human worlds of economics and politics, apparently governed by the same or similar laws. In fact, coevolution is according to John Holland a powerful force for emergence and self-organization in *any* complex adaptive system (Waldrop, 1992: 259). Cooperation between people, as will be analyzed later is often governed by game theory, as exemplified by the famous 'Prisoner's Dilemma'.[19] Biologists also often analyze coevolution in terms of game theory but it has to be consistent with the fundamental assumption that mutations occur at random with respect to prospective effects on fitness. Evolutionary biologist John Maynard Smith (1975) is one who has grappled with this, formulating a version of game theory for evolutionary biology by generalizing the idea of a Nash equilibrium[20] to that of an evolutionary stable strategy (ESS). He defined the concept of an evolutionary stable strategy as follows. At a Nash equilibrium, each player is better off not changing strategy as long as the other players play their own Nash equilibrium strategy. Similarly an ESS exists among a set of species when each has a genotype that it should selfishly keep as long as the other species keep their own ESS genotype. Each species has no incentive to change its strategy as long as the other species are 'playing' their ESS strategies. If any species were to deviate, its own fitness would fall.

Maynard Smith proposed that we think of the genotype, the genetic constitution of an individual organism, as a 'strategy' – the encoding for a set of traits and behaviours for playing the great game of survival. We should think of both organisms *within one* species, or organisms in *different* species as playing one another. As in the Prisoner's Dilemma, the 'pay off' to or 'fitness' of a given organism, with a given genotype, depends on the other organisms it encounters and plays.

The average fitness of an organism's genotype-strategy depends on its lifetime encounters. Each population of organisms may have the same genotype-strategy, or more than one. Also over time they may coevolve. At each generation, one or more of the genotypes in each of the coevolving populations undergoes mutations. These genotype-strategies then compete and the fittest ones spread most rapidly through the population. In other words, the organisms 'play one

another' and the rate of reproduction of each genotype is proportional to its fitness. In this way interacting populations within one species and populations between species coevolve.

To summarize, what has been described is the framework used by most biologists and ecologists studying coevolution. Two types of behaviour are visualized. Firstly, Red Queen behaviour, a kind of chaotic behaviour, where organisms continually change their genotypes in an ongoing 'arms race' such that coevolving populations never settle down to an unchanging mixture of genotypes. Secondly, more orderly ESS behaviour, in terms of which coevolving populations within or between species reach a stable ratio of genotypes, and then stop altering genotypes. In recent years much research has been undertaken and is still ongoing attempting to understand whether and when Red Queen behaviour or ESS strategies occur in real coevolving ecosystems. Also, over time the very process of coevolution itself undoubtedly evolves. Not surprisingly, Kauffman (1995: 221) suggests that there may be a phase transition between the chaotic, Red Queen, and the ordered, ESS, regimes and that the evolution of coevolution may lie in this domain, near the edge of chaos (Kauffman, 1995: 218-221).

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3.7 The Evolution of Coevolution

As has been described, Kauffman argues (1995: 221-236) that coevolution concerns populations that are adapting on coupled fitness landscapes. The adaptive moves of one population clambering toward the peaks of its landscape deforms the landscapes of its coevolutionary partners, and as these deformations occur the peaks themselves move. Adapting populations may succeed in climbing to the peaks and remaining on them, such that coevolutionary change ceases in terms of an orderly ESS regime. Alternatively, Red Queen chaos prevails as each population climbs uphill and landscapes deform so rapidly that all species perpetually chase after receding peaks. What transpires depends on the structure of the fitness landscapes and how readily each is deformed as populations move across them. Thus, coevolving systems are both complex and dynamic. In maintaining that a transition, a continuum, exists between the ordered ESS regime and the chaotic Red Queen regime it appears that the evolution of coevolution 'prefers' the phase transition. An ecosystem deep in the ordered regime is too rigid, too frozen in place to coevolve away from poor local peaks, whilst in the Red Queen chaotic regime species climb and fall on heaving fitness landscapes and, therefore, have low overall fitness.

Kauffman and Kai Neumann (Kauffman, 1995: 230-234) have run a series of computer simulations of simple models of organisms whose fitness landscapes are coupled to one another. They have looked into the conditions under which coevolving species will spontaneously evolve to the regime of highest average fitness. Their models allow each species to evolve on its own deforming fitness landscape and to evolve the ruggedness of its landscape by altering its own epistatic coupling level, which determines how interdependent they are. They also allowed for extinctions.

They found that it was *precisely* between ordered and chaotic behaviour that the very highest fitness occurs. Deep in the ordered regime, fitness peaks are low because of conflicting constraints. Deep in the chaotic regime, fitness peaks are high, but are too few and move too rapidly to be climbed. The transition regime occurs precisely at the point on the axis between the two where the peaks can just be climbed on the time scale available. A coevolving ecosystem, therefore, evolves until ESS equilibrium is reached, within a narrow range of intermediate landscape ruggedness where fitness is high and genotypes stop changing for considerable periods of time. That is, before an invader or invaders disrupt the balance by driving one or more of the adapted species to extinction. The average rate of extinction was found to be lowest where the average fitness was highest. The coevolving system appears to self-organize, or self-tune, to minimize the rate of extinction.

When one species is driven to extinction, the event may trigger a small or a large extinction avalanche that sweeps through some, or all, of the ecosystem. This is because when one species goes extinct it is replaced by an invader. The invader is new to the niche, is typically not at a local fitness peak, and therefore adapts in new ways that change its genotype. These moves change the fitness landscapes of its neighbours, usually lowering their fitness, and as their fitness is lowered they become successively more vulnerable to further invasion and extinction.

Extinction avalanches appear to obey a power law distribution. That is, there appears to be an inverse relationship between the number of avalanches and their size, measured by the number of species that go extinct. Plotting the logarithm of the size of an extinction avalanche and the logarithm of the number of avalanches results in a straight-line graph, there being many small avalanches and few large ones. Deep in the ordered and deep in the chaotic regime huge extinction avalanches occur because of the low fitness in both, making them vulnerable to

invasion and extinction. After a system self-tunes to optimal ruggedness and fitness, extinctions become rare whilst the avalanches of extinctions remain a power law. The slope of the graph also remains about the same. Thus, coevolving species appear to alter the rugged structures of their landscapes over which they evolve, such that on average all have the highest fitness and survive as long as possible. The self-tuning is another example of self-organized criticality at work (2.2.4).

3.8 Homeostasis and Autopoiesis

Homeostasis was referred to earlier when discussing the 'edge of chaos' (2.2.2) and James Lovelock's Gaia hypothesis (3.2). Autopoiesis on the other hand is also a concept that frequently crops up in systems theory and complexity studies.

Homeostasis is understood as the ability of a system to maintain stability by keeping its parameters within certain limits. It refers to the state of constancy in which systems, such as living organisms, may hold themselves even when their environment is changing. Homeostasis is based on feedback loops between a system and its environment and thus relies on circular causality to return the system to equilibrium, the goal of the system being stability. In ecology, if the environment is radically unstable a living organism will not achieve equilibrium and will ultimately perish. The concept was first applied to living systems but it is also applicable to mechanical and social systems too.

Homeostasis is not inconsistent with evolution, evolutionary explosions and extinctions or coevolution. Biological evolution does not usually proceed at a uniform rate. It often exhibits the phenomenon of 'punctuated equilibrium (Gould, 2002)[21] in which the genera and species stay relatively unchanged for long periods of time, and then undergo comparatively rapid change over a short period. These rapid changes constitute the punctuation in long periods of equilibrium, or homeostasis. The cause may be changes in the physicochemical environment or genetic changes within species themselves. Evolutionary bursts often follow massive extinction events. Coevolutionary organisms in a community strive to achieve an evolutionary stable strategy with respect to one another, to find equilibrium and optimal fitness. This will not be possible if there is not also stability in relation to the environment. An unstable environmental link, where homeostasis is not achieved will disrupt fitness landscapes. Extinction events are not only caused by endogenous processes within ecosystems. They may also be the result of

exogenous environmental changes and catastrophes, such as global warming, ice ages, meteors and volcanic activity.

Autopoiesis, or self-making, is a concept developed by the Chilean biologist/neurophysiologist, Humberto Maturana (*Autopoiesis and Cognition,* co-author Francisco Varela, 1980), to describe the essential feature of living systems; namely their power to generate themselves. The concept has a lineage going all the way back to Immanuel Kant, who thought of organisms as autopoietic wholes in which each part existed both for and by means of the whole, whilst the whole existed for and by means of the parts (Kauffman, 1995: 274). From an autopoietic viewpoint a system is a system precisely in the sense that its components interact with each other; none can be separated out from the whole. According to Maturana a living system never reacts to changes in the environment, only to changes within itself triggered by its structural coupling with the environment. Consistent with the premise of operation closure he denies causality and maintains that no information is exchanged between such a system and its environment. Events that happen in an environment do not cause anything to occur in the living organism. Rather they are historical occasions for triggering actions self-determined by the systems organization. The difference between an event 'triggering' an action and 'causing' an action may seem to be a quibble, but to Maturana it is crucial. The world of causality is the world of domination and control, with subject and object, mover and moved, transmitter and receiver. Hence for living systems the concept of operational closure with respect to information. If I hit you, you may be unhappy, but if you are a masochist it could please you (Hayles, 2000: 141).

In developing his concept of autopoiesis Maturana redefined homeostasis so that the circular causality no longer went from the system to the environment but was rather contained internally within the autopoietic process. He made the closure of the autopoietic space the necessary and sufficient condition for a system to be living. He kept the idea of a goal, but rather than stability the goal of autopoiesis is more autopoiesis. The crucial entity that had to remain stable to ensure survival was organization. A system's organization must persist unchanged through time for the system to retain its identity as such. However, change anywhere in the system drives the system toward a new configuration rather than back toward a prior equilibrium point (Hayles, 2000: 151-152), which would equate to self-organization.

Put this way, it appears as though autopoiesis may be amenable to narrative progression, despite the self-circularity of its theoretical structure. In *The Tree of Knowledge*, (1987),

Maturana and Varela attempted to articulate autopoiesis with the theory of evolution, that is, to reconcile the circular structure of autopoiesis with the narrative of evolution, which is about change and historical contingency. Unicellular organisms, progress to multicellular organisms with nervous systems and finally to cognitively aware humans. Humans are made up of cells, so if cellular mechanisms are at work in complex systems such as humans, in this way the end connects to the beginning. Autopoiesis, the continuing production of processes that reproduce themselves, is the governing idea that connects systems at all levels, from the single cell to the most complex thinking being (Hayles, 2000: 153).

 As Hayles states, the problem comes when the authors try to articulate this circular structure together with evolutionary 'lineages'. In evolution lineage carries both a sense of continuity and qualitative change as different lines proliferate and branch off from one another along separate evolutionary pathways. Maturana and Varela (1980) proclaim that for an organism to live it must conserve autopoiesis as well as adaptation and that it does this by remaining structurally coupled to its environment. As incremental changes occur in the environment, corresponding incremental changes also occur in the organism. Thus, the organism always remains within the circle of autopoiesis, but this circular motion can also move along a line, as when a ball rolls down a hill.

This articulation of autopoiesis with evolution therefore hinges on the claim that structures gradually evolve while still conserving autopoiesis. The Maturana and Varela describe this as 'natural drift' or elsewhere as 'structural drift' (1980: 47). But if structure changes, what do they mean to say that autopoiesis is conserved? They fall back on the distinction between structure and organization previously used in *Autopoiesis and Cognition:* "Organization denotes those relations that must exist among the components of a system for it to be a specific class. Structure denotes the components and relations that actually constitute a particular unity and make its organization real". Interestingly they use a mechanical rather than a biological analogy to illustrate the distinction. A toilet's parts can be made of wood or plastic; these different materials correspond to differences in structure. However, regardless of material used it will still be a toilet if it has a toilet's organization (1980: 47). As Hayles points out (2000: 154), the analogy is strangely inappropriate for biology. For life forms based on protein replication, it is not the material that changes but the way the material is organized.

Thus, either organization is conserved and evolutionary change is effaced or organization is changed and autopoiesis is effaced. The circle cannot be seamlessly articulated with the line, for the tree Darwin used to image descent has a branching structure at odds with circularity of autopoiesis. Further, genetics is hardly mentioned by Maturana and Varela. Conserving organization means conserving life. This may be adequate to qualify autopoiesis as a property of living things but does nothing to articulate or reconcile and explain autopoiesis with or in terms of evolutionary change (Hayles, 2000: 156).

3.9 Increasing Complexity with Time and Frozen Accidents

Reality, by reason of its web of relationships, is by its very nature is complex. A myriad of factors, elements, and energy forms continually interact, sometimes in synergy and harmony but sometimes in conflict and explosively, creating the universe, its galaxies, our solar system, the Earth, its ecosystems, its life forms and societies. The complexity of self-reproducing, self-organizing, living organisms is particularly intense. But, whether in the domain of the physical world, the biological world or in the human realm as time progresses there is a tendency for complexity to increase. Sometimes changes occur that result in a reduction of complexity but the overriding trend is more often toward higher complexity. Can this be explained?

As discussed in 2.1.2, complexity can be defined by the length of a concise description of the regularities of a system. In our complex world many of the regularities we observe can be traced back to the fundamental physical laws governing the universe. Others arise from the fact that many characteristics of a given part of the universe at a given time are related to another through their common origin in some past incident. Hence, they have characteristics in common. An analogy would be cars of a given model resembling one another because they all originate from the same design. However, they contain many arbitrary features which could have been chosen differently. Such phenomena are called 'frozen accidents', and can be felt in many different ways. For example, had King Edward VIII not abdicated the British throne the current Queen would not be the Queen and a different head would be on British coins.

If one finds a fossil in a rock, how can we deduce from fundamental laws that there are probably more fossils of a similar kind? The answer is: by using the initial condition of the universe as well as the fundamental dynamical laws. We can then utilize the tree of branching histories and argue, starting from the initial condition and the resulting causality, that the existence of the

found fossil means that a set of events occurred in the past that produced it, and that those events are likely to have produced other such fossils, ... or coins. A frozen accident may even explain why the four nucleotides, abbreviated as A, C, G and T, constitute the DNA of all living organisms on Earth, for planets orbiting distant stars may habour complex adaptive systems that closely resemble terrestrial life but utilize genetic material composed of other molecules (Gell-Mann, 1994: 227-228).

As Gell-Mann says, "The tree-like structure of branching histories involves a game of chance at every branching. Any individual coarse-grained history consists of a particular outcome of those games. As each history continues through time, it registers increasing numbers off such chance outcomes. But some of those accidents become frozen as rules for the future, at least for some portion of the universe. Thus, the number of possible regularities keeps increasing with time, and so does the possible complexity" (1994: 229).

As stated earlier this applies not only in the world of living things, the world of complex adaptive systems. The evolution of physical structures in the universe shows the same trend toward the emergence of more complex forms through the accumulation of frozen accidents. As the entropy, the overall disorder, of the universe increases, self-organization can produce local order, as in the arms of a spiral galaxy or the multiplicity of symmetrical forms of snowflakes.

After an enormously long time period, even on a cosmological scale, as the universe continues to expand, it will become very different. Cosmologists predict that stars will die, blacks holes will become more numerous and then decay, protons will decay and all the structures that we are familiar with will disappear. Regularities will become fewer and fewer, the universe will be describable in terms of randomness, and entropy will be very high. Between now and then, if this picture is correct, the emergence of more and more complex forms will gradually come to a halt and regression to lower complexity will become the rule.

However, much of this thinking is little more than conjecture and of little practical value to us today. In the meantime here on Earth the characteristics of our planet and our sun have provided frozen accidents that profoundly affected the rules of the environmental sciences, inter alia, geology, meteorology and biology. The evolution of the physical Earth and of the biosphere, the emergence of life, the bursts of evolution and the catastrophic extinctions interrupting and changing the course of developments, leading up to the splendid diversity and

complexity of our world of today, are all are testimony to an accumulation of frozen accidents. At the same time, biological evolution, in particular, has given rise to the emergence of higher and higher effective complexity (Gell-Mann, 1994: 230-231).

The Earth is a huge complex adaptive system. The challenge for humankind is to adapt to it, survive and flourish.

CHAPTER FOUR

LIVING IN OUR COMPLEX WORLD

In a recursive, complexly interwoven world, whatever one does propagates outward, returns, recycles and comes back in a completely unpredictable form. We can never fully know to what result our action leads. We take action, the action can have a very potent shaping effect. Then we relax the drive to control and allow the process to unfold – the process learns, shapes and changes itself through all its inseparable components, not under the direction of one of them only. Together with overall changes in the process, we also change, almost unnoticeably, without any strain.

Sally J. Goerner[22]

Having demonstrated the complexity of the Earth it is, perhaps, not surprising that the human world is equally complex and is becoming increasingly complex as time progresses. Understanding our world and adapting to it so as to survive and flourish, calls for a new mind set. In Western Europe, in the modern world of the Enlightenment era the approach to science, the economy and society tended to be predicated on linear thinking, control and predictability. This met with considerable success and achievement. But, in the postmodern era we now find ourselves struggling with problems which requires that we fully recognize the often unpredictable, organic and nonlinear nature of things. In this section the complex nature of the human realm and approaches to living in our complex world will be identified and discussed.

4.1 Complexity, Economics and Business

4.1.1 The Global Economy as a Complex Adaptive System

In a world where both the globalization of business and rapid accelerating technological innovation and change is impacting society everywhere, it is appropriate to consider the global economy as one massive complex adaptive system. The world of business shares with the natural world fundamental properties and processes. Economies and business are complex adaptive systems composed of a diversity of agents that interact with one another and mutually

71

affect one another in ways that are often unpredictable. Such systems evolve and novel properties of the systems emerge as they adapt and change to their environment, which itself may be ever changing. As in nature, the struggle to survive and succeed is to struggle in a world that is dynamic and uncertain. Traditional linear, reductionist approaches to understanding the world are no longer sufficient. While not to be rejected totally out of hand, the limitations of such mechanistic approaches are becoming obvious in a human world in which the degree of complexity is multiplying at what many would regard as a disturbing rate.

The network character of the world economy is becoming ever more apparent. The metaphor of the economy as an 'ecosystem' is even being used:

> *When we understand that the economy is an ecosystem – not a machine isolated and insulated from the environment – we grasp fundamental truths about what makes the economy work.*
> *John Baden[23]*

As in nature, where there are systems within systems (living organisms within species, species within communities and communities within, say, a forest and forests in an ecosystem … and the ecosystem within Gaia) so there are systems within systems in business. Individuals and their collective behaviour as employees of a company constitute a complex adaptive system. But every company is located in a larger complex adaptive system in, say, the market sector or regional economy in which it operates, and that economic sector is situated in a larger system, such as a national economy, ultimately embedded in the global economy. Accordingly, there is much to be gleaned by rethinking economic theory, in the same way that the study of biology and ecology has shifted and continues to evolve since Darwin expounded his theory of evolution.

Neither nature nor the global economy and business are simple and predictable, all being complex, dynamic, unpredictable and usually far from in equilibrium. Businesses evolve in ways that organisms evolve. They mutate, they coevolve, they compete, they co-operate, they exhibit Red Queen behaviour and evolutionary stable strategies, operating most efficiently in the phase transition between order and chaos. They adapt to their fitness landscapes and as they do they can deform the landscapes of their neighbors, which may be customers, competitors and or suppliers. Businesses can become extinct, either as a result of external factors, such as

technological changes, changes in government regulations, war or natural disasters. Or, as is often the case, the internal dynamics of the business ecosystem itself may be the cause, as it is with living organisms. It is difficult to think of a characteristic of natural complex adaptive systems that is not paralleled in someway in the business world. The list is endless. Technical evolution like the evolution of living organisms often exhibits an early explosion, in the form of a branching radiation of diverse forms. There is then a learning curve period, a period of exploration of possibilities on rugged fitness landscapes, under the selective pressure of market forces, until only a few dominant designs survive. That is, at least for a time, until an entirely new 'fitter' mutant species, a new innovation or technology is discovered, evolves and displaces an existing one. This can lead to an avalanche of extinction of existing businesses. In the natural world the extinction of a type of grass may lead to the extinction of certain herbivores that live on it, and in turn to certain carnivores that eat them. In the business world new technology can render a company's products obsolete and force it to close. This can force the closure of suppliers, and the overall redundancy of workers can force the closure of shops in a particular area. In the meantime, a new burst, a new round of the evolutionary process may then occur arising from another new technological 'invasion'.

Frozen accidents, which lead to features being essentially locked in forever, are common to both the natural world and the business world. They arise in the game of chance that is common to the branching history of evolution in nature and technical innovation. For example, certain right-handed molecules play an important role in the chemistry of life while the corresponding left-handed ones are not found in those roles. It is easy to understand why right-handed molecules are compatible with one another, but what determined that they be right rather than left-handed ones (Gell-Mann, 1994: 228)? The QWERTY keyboard layout, designed in 1873 by Christopher Scholes, specifically to slow typists down so as to prevent the jamming of early machines, is the one used on virtually every computer and typewriter keyboard in the Western world. It is not, by far, the most efficient possible arrangement, but imagine the implications of changing it, now that it is the standard for many millions of people (Waldrop, 1992: 35).

There is one significant difference between the natural world and the business world. Businesses, like species in an ecosystem, exist in a community with a rich network of connections. They share fundamental properties with their natural counterparts. But, in nature

there is not the same conscious intent (unless, from a religious standpoint, one ascribes that to a God) that there is in human society where people make conscious decisions everyday.

4.1.2 Business Management in a Fast Changing Environment.

Business organizations and companies are complex adaptive systems in which the agents are people and the connections and interactions are the relationships among them. In the fast moving world of today most businesses will only survive and succeed if the companies are recognized as such systems, if the fundamental properties and processes of complex adaptive systems are understood and the companies are able to, and are allowed to, continually adapt and evolve. This requires managers to adopt a new mindset quite different to that associated with long-established business models. In our complex world managers and executives should not try to control their organizations to the degree they did in the past. Their emphasis should rather be on influencing where the company is going, and how it evolves.

Management theory has undergone many revisions since the Industrial Revolution, particularly with the thinking of people like Peter Drucker who emphasizes that businesses are communities.[24] But, the machine model of business, with a corresponding command and control style of management, is still the norm. The message from the study of complex systems is that managers should create a culture and endorse practices within their organizations that facilitate the emergence of creativity. Applying principles derived from an understanding of how complex adaptive systems operate leads to the adoption of a very people-orientated business style.

Relationships characterized by mutuality should be encouraged at al levels, among people themselves, teams and companies in order for novelty to emerge. This is not to imply that there should be no control. Structure is necessary. It is the nature and degree of control that needs to be examined and set appropriate to existing and foreseen circumstances. Computer simulation models of complex adaptive systems can be tuned to an orderly, static state, a chaotic state or to an intervening zone of creativity … the edge of chaos. Strict control tends to confine companies to the static state, minimizing interactions and impeding the emergence of creativity. The challenge for managers, and for anyone working in a business, is to encourage interaction

within the organization and with outsiders, thereby increasing the potential for creativity, but to do it in such a way that there is not a collapse, over the edge, into chaos.

This does not mean that periods of chaos are always a bad thing. They may be desirable at times. For example, when old ways of doing things are no longer appropriate and new ways need to be found, a brief chaotic period can facilitate the exploration of different innovative possibilities. Likewise, mechanistic management can also be appropriate when goals are clear and there is little uncertainty in the prevailing business environment. Just as natural complex adaptive systems may fluctuate from homeostasis to chaos with a tendency to thrive in the transition zone, so too will companies and economies similarly fluctuate. Complexity modelling indicates that emergent order will be richer, more creative and adaptable if there is a diversity of agents with different characteristics and different behaviours. The message to managers is clear. Encourage diversity to achieve creativity and adaptability. Empower people and they will self-organize to address problems that need to be solved (Lewin, 1999: 198-203).

Because businesses are complex adaptive systems operating in a larger complex adaptive system there will always be surprises, despite careful planning. Accordingly, over-precise planning has its own inherent flaws since a too linear approach is doomed to fail because business environments constantly change. Scenario planning makes sense whereby alternative futures are forecast. Strategies are then developed to address particular outcomes so that as events occur and the overall picture emerges the company can react and adapt quickly, innovatively and appropriately to the prevailing business environment. Strategic planning should not be overly prescriptive. If the appropriate conditions are in place for creativity to emerge solutions will be found to problems.

4.1.3 Coevolution in business

As with an organism in an ecosystem, a company's ability to survive and grow depends on the market niche it is filling, what other companies are around, what resources and technology it can gather, and what its past history has been. Companies continually coevolve with each other, both competing and cooperating within an economy. Each company is free to organize itself however it likes internally, but a network of contracts and regulations fixes its relationships with other companies. Nevertheless, within these constraints there is plenty of room for coevolution and growth.

Companies move around on their fitness landscapes. The predominant direction is always upwards to great fitness levels. In business, strategies that fail tend to lead to liquidations and the demise of companies. As in nature the whole point of coevolution is that companies' individual landscapes are not independent. They are coupled. What is a good strategy for Coca Cola will depend on what Pepsi is doing. Landscapes are deformed as they interact, either due to each other's actions or external factors. For example, government actions, such as tax changes or new regulations that can affect the companies themselves or the behaviour of their consumers (Waldrop, 1992: 310).

Businesses survive by creating and selling goods and services that make economic sense in the niche afforded them by other goods and services. An economy, like an ecosystem, is a web of coevolving agents. From time to time there are periods of creative destruction, when new technologies come into existence and old ones are rendered obsolete, possibly leading to the demise and extinction of some companies, or even whole sectors of an economy, and the creation of new ones. The arrival of the automobile ensured the demise of the horse and buggy as a means of transport. With the horse and buggy went the whip, the smithy and the saddle maker. In came the oil industry, the paved road, motels and shopping malls.

Small and large avalanches of technology propagate through economies as they do through ecosystems, and show similar power law distributions. For companies, as for organisms and species, infant mortality is high. Older companies and species are more resilient. A new company in an economy much like an invading species is of low fitness in its new niche, and is vulnerable to displacement in turn by other new invaders. Moreover the coevolutionary turmoil it induces in its specific area of operation keeps its fitness low. But as it and its region climb toward ESS (evolutionary stable stategy) equilibria, its fitness increases and it becomes less vulnerable. As companies mature they become well capitalized, capture market share and hold it. Once so established they are not rapidly driven out of business; until, perhaps, a new wave of technical change or other exogenous factor comes into play (Kauffman, 1995: 240-242).

4.1.4 Organizational Autopoiesis and Self-Organization in Business

Companies and similar organizations are open systems that are subject to diverse external and internal forces the combination of which gives rise to complex, and at times chaotic

organizational dynamics. If managers and employees are unable to cope satisfactorily with these dynamics the result for the company is either fixed order rigidity or uncontrolled chaos and collapse.

Accordingly, in order to flourish and survive, companies must be able to reproduce their specific organizational dynamics, that is the internal forces and factors that stimulate development and change. They must evolve and shape themselves in a vital structural coupling with the ever-changing dynamics of their environment. This is what Vladimir Dimitriv and Lloyd Fell (2003) have called *organizational autopoiesis.* According to these authors self-organization is the essential force in the process of organizational autopoiesis. Without a self-organizing ability in a company there will be no self-renewal process and it will not flourish and grow. In this context, where self-organization becomes autopoiesis is perhaps a moot point. As was discussed in 3.8, a means of reconciling autopoiesis with evolution is not readily found, but it is an academic challenge which need not trouble one here.

One of the key characteristics of organizational autopoiesis and self-organization in business is the lack of clear linear cause-and-effect relationships, for so interwoven and entangled are the factors influencing organizational dynamics that it is often extremely difficult to define what factor or factors caused an observed effect. A constant innovation process is necessary in order to remain successful, for decisions that have led to beneficial outcomes in the past will not necessarily lead to beneficial results in the future. In order for such a process of innovation to thrive an organization will have to operate in a state between rigid order and random chaos (you've guessed it, the edge of chaos). When an organization is too ordered it us unable to adapt, to exploit its inherent creative ability, sufficiently to maintain long term viability. On the other hand, extreme disorder and chaos could result in a sea of change overwhelming the organization.

The self-organizing forces of a company are the flow of ideas, the drive, passions and burning emotions of its employees. Often hidden, it is the challenge of managers to encourage these forces to emerge, for it is the intense interaction of such forces that should lead to advancement through continuous organizational self-renewal. The ability of all managers and employees to inspire and ignite imagination, to stimulate new thoughts and vision, to awaken hopes and aspirations is what drives organizational autopoiesis.

The concepts of organizational autopoiesis and self-organization can help managers to understand their organizations better, to avoid wasting time and energy trying to force complex organizational development in an over-planned non-negotiable direction, instead of merely guiding processes. The unpredictability of complex behaviour should not be seen as an obstacle. On the contrary, by exploring the apparent unpredictability of complex situations and systems, managers and employees can gain insights with enormous predictive power.

Managers should not expect steady states in their organization's dynamics. They must learn to deal with critical states in a world of often unpredictable emergent phenomena. They need to discover what fields of activity inspire and concentrate the energy of the employees, what can cause such energy to dissipate and whether there are any hidden forces responsible for bringing forth specific organizational dynamics.

A successful company is one that is constantly innovating and producing new solutions to old and new problems. Self-organization and autopoiesis never emerge in organizations that seek to maintain equilibrium, for equilibrium and these concepts are incompatible in business. With goodwill, honesty, humility, and the sincere desire to help and support, self-organization and organizational autopoiesis will liberate the potential of people and organizations for creativity and growth (Dimitrov, 2003: 1-6).

4.1.5 Forecasting and Planning

This subject was touched on in 2.3.3. It can be extremely difficult to predict the future behaviour of a complex system in times of dramatic change, even though it is often vitally important to foresee the consequences of current actions, or conversely, the lack of action, whether it be in business, politics or everyday life. There are many stories of mistaken foresight in business. IBM, for example, even as the then dominant world player in the computer industry, missed out on the personal computer boom because its leaders at the time believed that a handful of computers would suffice for the entire world.

The unanticipated Internet explosion is a very recent development that is transforming the way we live and work, to the extent that we now live in an age when an Information Revolution is taking place. The consequences of it for humankind already rival the impact the Industrial Revolution had on 19th Century Europe. As time goes on it will inevitably exceed it. It is

78

changing the way of life of billions of people, socially, economically and politically. From a complexity viewpoint what is novel about the World Wide Web is that it has a dynamism of its own, with no central control. It is a truly complex adaptive system, the full implications of which will probably be as unanticipated as was its own creation.

When experts are challenged to forecast the future and its requirements in complex situations their customary response is to acknowledge the difficulty of prediction and then do the best they can with their particular expertise (Axelrod, 2000: 12). This may amount to little more than a 'best guess', even though it might involve the use of sophisticated modelling techniques and computer simulations. This will be the case even though their analysis will undoubtedly take cognizance of the constraints and resources (interalia, capital, technical and human) available to the system under study, as well as the necessary knowledge and information about its history and environment. This information should reflect patterns of behaviour, such as price fluctuations and consumer preferences under various and varying conditions. It should also identify threats of competition from, and opportunities for alliances with, other participants within the system under review, such as the market sector of an economy.

A widely adopted response to the difficulty of prediction is offered by scenario generation, a method that has been used with some considerable success, by the people such as Pierre Wack at Shell and Clem Sunter at Anglo American. Scenario generation and scenario planning entails identifying the driving forces of, and dominant factors pertaining to a situation, and then developing policies that are robust in the event of a range of possible outcomes involving changes to currently predominant influences. It is all about being ready with some appropriate response as the unlikely, or the unexpected, materializes. The approach requires an ability to identify correctly the principle driving forces in a system, and understand how they will affect the outcomes of interest. This is where the skill lies. If the driving forces remain obscure scenario generation becomes very difficult (Wilkinson, 1995).

What makes forecasting and prediction difficult in complex systems is that the driving forces shaping the future do not add up in a simple, linear manner. There are many non-linear interactions among the components of the system. Frequently the conjugation of a few small events can produce a large effect and the overall effect can be unforeseeable if their consequences diffuse unevenly through the interaction patterns within the system. At other times a large event can have little overall effect because of other contrary factors in play.

Our world is indeed a complex world. It is a world of avalanches, of founder effects, where small variations in an initial population can make large differences in later outcomes, of self-restoring patterns, where large disturbances do not ultimately matter, and of apparently stable regimes that suddenly collapse. It is a world of punctuated equilibria, where periods of rapid change can alternate with periods of stability, and butterfly effects where a small change in one place can cause a large effect in a distant place. It is also a world where change can keep recurring in a fixed pattern (Axelrod, 2000: 14).

The difficulty of prediction in complex systems does not make the situation hopeless but it does require a different way of thinking and a different set of conceptual strategies to the classical mechanistic, reductionist, approaches of the past. There is a tendency for managers and policy makers to regard complexity as a liability and attempt to control or eliminate it (Axelrod, 2000: xi). This can amount to attempting the impossible. The thesis of Robert Axelrod and Michael Cohen is that the dynamism of complex adaptive systems, in business and in any field, can be used for productive ends, that it can be taken advantage of, and that it can be harnessed. Hence the title of their book, *Harnessing Complexity* (2000). In it they have developed a framework for harnessing complexity that complements and strengthens conventional and scenario-building approaches to forecasting and planning.

4.2 Harnessing Complexity

Axelrod and Cohen begin by asking what actions one should take in a world with many diverse mutually adapting players, where the emerging future is extremely hard to predict. They answer this by proposing a framework for harnessing complexity in terms of a complex adaptive systems approach. We all intervene in such systems on a daily basis. We all face situations where formulating alternative actions and forecasting their likely consequences assumes more understanding and predictive power than we actually have (Axelrod, 2000: 160).

Their approach takes account of the dynamic and multi-layered reality of our social world. It reduces the extreme simplifications that are common to other approaches in the social sciences. It accommodates agents (people and strategies) situated in the rich fabric of social interaction, whose preferences may change with their experiences. It also allows for the formation of new kinds of actors, or the disappearance of existing ones, rather than by ignoring

history and assuming stasis. All these are important in social analysis, but often difficult to incorporate into most current approaches.

The aim of Axelrod and Cohen is to provide a coherent scheme for managers, planners and policymakers to intervene and prosper in a complex world. Their framework illustrates how scientific insights into the complex criteria of variation, interaction and selection fit together and may be used to harness complexity (Axelrod, 2000:159-160). They identify sixteen means by which this may be done (Axelrod, 2000:178) and they give eight examples illustrating the kind of action that takes advantage of complexity (Axelrod, 2000:155-158).

In their book Axelrod and Cohen discuss in detail the roles of variation, interaction and selection. I have summarized these criteria below, highlighting five means of harnessing complexity in terms of variation, five in respect of interaction and six that constitute selection criteria. Examples of actions in terms of the three criteria are described.

The Role of Variation.

i)   Variation provides the raw material for adaptation, but there must be the right balance between variety and uniformity.
ii)   Simplifications can be made but variety must be accommodated and taken account of.
iii)   Variety can be altered, being increased or decreased, appropriate to circumstances.
iv)   By distinguishing types, or categories of agents, with a detectable combination of features, the analysis of variety can be facilitated.
v)   Constraint relaxation is frequently used in problem solving. Solutions to a hard problem can be sought by generating variants that violate situational constraints.

Examples:

Arrange organizational routines to generate a good balance between exploration and exploitation.
This principle captures the tension in complex adaptive systems between the creation of untested types or strategies that may be superior to what currently exists (exploration) versus the copying of tested ones that have so far proved best (exploitation). This theme can be clearly seen in personnel policy. In the short run, it pays to promote the person who best fits the current

vacancy (exploitation). In the long run, it may be better for an organization to sacrifice short-run gains to promote and develop people who will provide a better set of options in the future (exploration).

Link processes that generate extreme variation to processes that select with few mistakes in the attribution of credit.
Often the problem facing designers or policymakers is not how to foster variety, but whether to do so. Each situation has to be carefully analyzed to determine what factors reduce the costs or increase the benefits of exploring relative to exploiting.

The Role of Intervention

i)   In designing interventions the objective is the improvement of some measure that it is deemed desirable to promote. Usually interventions involve the manipulation of spaces, either the physical space where an interaction takes place or is likely to take place, or conceptual space, such as a person's location on a company's hierarchical organization chart.

ii)   A manager, designer or policy maker may also have the opportunity to manipulate the role of timing. Different sequences may be possible in a given process.

iii)   Under certain circumstances preventative intervention may be necessary to stave off a catastrophe when an event in some quarter could trigger a large chain of effects.

iv)   This could be done by building slack into a system, in order to obviate the risk of cascading failures where systems are closely coupled.

v)   Alternatively the coupled structure of the system could be changed by some means of partitioning.

Examples:

Build networks of reciprocal interaction that foster trust and cooperation.
One way to do this is to promote associations that provide the basis of social capital. Northern Italy's advantage over the South can be traced back to hundreds of years of communal republics, guilds and religious fraternities. Today, following the tradition, the North still benefits from a rich network of organized reciprocity and civic solidarity fostered by cooperatives, mutual

aid societies and neighborhood associations supporting good government and economic progress (Putnam, 1993).

Assess strategies in light of how their consequences can be spread.
AIDS research shows that it is important to take into account that interactions do not happen at random. Different modes of sexual interaction have different risk profiles when it comes to the spread of AIDS.

Promote effective neighbourhoods.
 In computer simulated research by Rick Riolo (1997) on 'tags' in the 'Prisoners Dilemma' game, identity tags (a random number value between 0 and 1) were assigned to agents who were then programmed so that they tended to avoid playing with agents whose tag was not similar to their own. The results showed that there can be tremendous gains by encouraging would be co-operators to interact more frequently. In many situations, physical locations or social signalling devices, such as clothing, can perform the same role.

Do not sow failures when reaping small efficiencies.
There can be significant risks from efforts to link processes not previously connected. For example, excess demand can be shifted among linked electric power grids or computer networks, but if the wider system fails, it does so on a larger scale, as it did recently in a vast area of North America when the power system failed. The risks may be worth the gains, and good designs can minimize them, but the risks should not be overlooked.

The Role of Selection
i) Selection entails deciding which agents or strategies should be copied and which should be eliminated. It entails assessing alternatives in order to promote adaptation.
ii) How success is defined affects the chances for effective learning. The measures of success must correlate with what ultimately matters and must be set and, if necessary, changed accordingly.
iii) In the selection of agents or strategies the appropriate selection pressure must be applied. Strong selection pressure exploits and amplifies the success of the best but it can quickly destroy variety. A balance must be sought.
iv) Setting goals is important.

v)   Selection can also involve creating, altering or destroying types (i.e. categories of agents or strategies).

vi)   What a leader does is especially likely to be copied by others. Accordingly, visible leadership that sets a good example helps establish beneficial norms in a community.

Examples:

Use social activity to support the growth and spread of valued criteria.
Research carried out on prize competitions reveals that the process of refining prize criteria, the careful selection of judges, the careful selection of award nominees, and publicizing winners can all serve to promote and disseminate the underlying goals that were the motivation for the prize. The result of such activity is to increase the use of the criteria embodied in the competition.

Look for shorter-term, fine-grained measures of success that can usefully stand in for longer-run, broader goals.
By examining the use of simulation in military and business affairs Axelrod and Cohen found that there can be severe shortages of experience necessary to drive adaptation in complex adaptive systems. While being alert to the risks of misattribution it can sometimes be valuable to find ways to get experience quickly, even if it is of lower validity. Simulations can do this.

4.3 Cooperation

In a complex adaptive system the interactions between autonomous agents is an important aspect of the system. They self-organize in a coevolutionary manner either by competing or by cooperating. In society this is what we all do as human beings. The need for cooperation is fundamental to the success and flourishing of individuals, and of human society itself as a complex adaptive system.

Thomas Hobbes believed that, before governments existed, the state of nature was dominated by the problem of selfish individuals who competed on such ruthless terms that life was "solitary, poor, nasty, brutish and short" (Hobbes, 1651/1962: 100). In his view, cooperation could not develop without central authority, without strong government. Yet cooperation does emerge in many actual and potential conflict situations where there is no central authority. In a much discussed book, *The Evolution of Cooperation* (1984), Robert Axelrod explored how cooperation

can emerge in a world of self-seeking egoists – whether national governments, businesses or individuals – when there is no central authority. Cooperation can emerge in conflict situations principally because the pursuit of self-interest can lead to a poor outcome for all.

The famous Prisoner's Dilemma is a means of representing what is common to such situations, without becoming bogged down in the details. One will recall that in the Prisoner's Dilemma there are two prisoners, arrested for a crime they both committed, are separated and offered a choice by the police: inform on your partner and receive a reduced sentence, or remain silent. If both remain silent, both go free, but if one prisoner informs, the other receives the maximum sentence. If both inform they both go to prison, but with lighter sentences. Thus each has two choices: cooperate (remain silent) or defect (inform). Each must make the choice without knowing what the other will do. No matter what the other does, defection yields a higher pay off than cooperation. The dilemma is that if both defect, both do worse than if both cooperated. The Prisoner's Dilemma is simply an abstract formulation of some very common situations in which what is best for each person individually leads to mutual defection, whereas everyone would have been better off with mutual cooperation.

Prisoner's Dilemma can be turned into a game as illustrated in Figure 11. One player chooses a row, either cooperating or defecting. The other player simultaneously chooses a column, either cooperating or defecting. Together, these choices result in one of four outcomes. The game should be played several times. As a part of the game's definition, the reward for mutual cooperation (R=3) is greater than the average of the temptation and the suckers payoff ((S+T)/2=2.5). Accordingly, the players cannot get out of their dilemma by taking turns exploiting each other.

	Cooperate	Defect
Cooperate	R=3, R=3 Reward for mutual cooperation	S=0,T=5 Sucker's payoff, and temptation to defect
Defect	T=5,S=0 Temptation to defect and sucker's payoff	P=1,P=1 Punishment for mutual defection

The payoffs to the row chooser are listed first.

Figure 11.

Prisoner's Dilemma.

If the game is played a known finite number of times, the players still have no incentive to cooperate, since on the last move the dilemma remains as there is no future to influence. However, if the players are to interact an indefinite number of times this reasoning does not apply. And in most realistic settings, the players cannot be sure when the last interaction will take place. As will be discussed, with an indefinite number of interactions, cooperation can emerge. The issue then becomes the discovery of the precise conditions necessary for this.

In life a player may be interacting with many others and for the purposes of Axelrod's analysis the player was assumed to be interacting with them one at a time. A player was also assumed to recognize another player and to remember how the two of them had interacted so far, thereby allowing the history of their play to be taken into account in a player's ongoing strategy (Axelrod, 1984: 8-11).

Axelrod explored the emergence of cooperation through the study of what is a good strategy to employ with a repeated sequence of Prisoner's Dilemma games. He set up a computer tournament for which professional game theorists were invited to submit their strategy. Each strategy was played against each of the others to determine which was the most successful. Surprisingly, the winner was the simplest of all. This was TIT for TAT, a strategy that cooperates on the first move and then copies what the other player did on the previous move. A second round of the tournament was conducted in which many more entries were submitted, by amateurs and professionals alike. All of them knew the results of the first round. The result was another victory for TIT for TAT.

Analysis of the data from these tournaments reveals four properties that tend to make a decision rule successful:
i)   Avoidance of unnecessary conflict by cooperating as long as the other player does.
ii)   Provocability in the face of an uncalled for defection by the other.
iii)   Forgiveness after responding to provocation.
iv)   Clarity of behaviour so that the other player can adapt to one's pattern of action.

The results of the tournaments demonstrated that under suitable conditions, cooperation can indeed emerge in a world of egoists without central authority. Such a condition for the evolution

of cooperation would be that individuals have a high chance to meet again so that they have a stake in their future interaction. This being the case, cooperation can evolve in three stages:

(i)   Cooperation can get started even in a world of unconditional defection. The development cannot take place if it is tried only by scattered individuals with little chance to interact. However, cooperation can evolve from small clusters of individuals who base their cooperation on reciprocity and have even a small proportion of their interactions with each other.

(ii)   A strategy of reciprocity can thrive in a world where many different strategies are being tried.

(iii)   Cooperation, once established on the basis of reciprocity, can protect itself from invasion by less cooperative strategies. Thus, the gear wheels of social evolution have a ratchet.

A fascinating example that demonstrates these results is the 'live and let live' system that emerged during Word War 1. In the midst of this bitter conflict, on some occasions the front-line soldiers refrained from shooting to kill – provided their restraint was reciprocated by soldiers on the other side. For example, during bad weather it was almost impossible to undertake major aggressive action. Ad hoc weather truces emerged, and when the weather improved, the pattern of mutual constraint often continued. What made this mutual restraint possible was the static nature of trench warfare. The soldiers of these opposing small units actually violated orders from their own high commands so as to achieve tacit cooperation with each other. Thus, when the appropriate conditions are present cooperation can emerge and prove stable even in situations that are otherwise extraordinarily unpromising. The 'live and let live' system show that under suitable conditions cooperation based on reciprocity can develop even between antagonists.

Working with evolutionary biologist William Hamilton, Axelrod has also shown that cooperation can also emerge even without foresight. This was done by showing that 'cooperation theory' can account for the patterns of behaviour found in a wide range of biological systems, from bacteria to birds. Cooperation in biological systems can emerge even when the participants are not related, and even when they are unable to appreciate the consequences of their own behaviour. What makes this possible are the evolutionary mechanisms of genetics and the survival of the fittest. An individual able to achieve a beneficial response from another is more likely to have

offspring that survive and continue the pattern of behaviour that elicited beneficial responses from others. Thus, under suitable conditions, cooperation based on reciprocity also proves stable in the biological world. The conclusion is that Darwin's emphasis on individual advantage can account for the presence of cooperation between individuals of the same or even different species.

While foresight is not necessary for the evolution of cooperation it can certainly be helpful. In a Prisoner's Dilemma game a player's objective is to do as well as possible, regardless of how well the other player does. Based on his tournament results Axelrod offers four suggestions for individual choice:

i)   Do not be envious of the other player's success.
ii)   Do not be the first to defect.
iii)   Reciprocate both cooperation and defection.
iv)   Do not be too clever.

Understanding the perspective of a participant can also serve as the foundation for seeing what can be done to make it easier for cooperation to develop among egoists. Methods identified by Axelrod were, making the interactions between participants more frequent and more durable, teaching participants to care about each other, and teaching them to understand the value of reciprocity.

Axelrod's study of the emergence of cooperation among egoists without central authority lead into an analysis of what happens when people actually do care about each other and what happens when there is central authority. The principal finding was that if the facts of cooperation theory are known by participants with foresight, particularly the benefits of reciprocity, the evolution of cooperation can be speeded up (Axelrod, 1984: 20-24). Axelrod suggests, possibly incorrectly, that altruism is a good name to give to the phenomenon of one person's utility being positively affected by another person's welfare and that altruism is thus a motive for action. He point out that many actions that aim to improve another's welfare are not entirely selfless (1984: 135), but a strict definition of altruism is a <u>selfless</u> concern for the well-being of others.

Leading on from these insights from Axelrod's cooperation theory, as it applies to both complex adaptive systems of the natural world and complex adaptive system of human society, it is apposite to now examine the question of ethics in a complex, postmodern world.

4.4 Ethics, Postmodernism and Complexity

Whether or not one accepts the term 'postmodern' to describe the world of today it is indeed complex, and to survive and flourish in it we need an appropriate set of ethics to do so. However, before dealing with what is undoubtedly a complex subject, it is important to define and be clear as to what is understood by the terms 'post modernism', 'ethics' and 'postmodern ethics'. In section 2 a comprehensive description of complexity and complex systems was given, but what is meant by these other terms?

4.4.1 Postmodernism

What is postmodernism? And for that matter, what is modernism? Attempting to answer these questions could fill several volumes, but here brief summaries must suffice. The word 'modern' suggests a rejection of what has past, a new set of ideas, the 'latest', and the best. Historically the modern period is taken as beginning at the commencement of the 16th century, around the time of Christopher Columbus and the discovery of the 'New World' by Europeans, and the Reformation of the Church in Europe after Martin Luther (1483-1546). The defining philosopher of modernity was Rene Descartes (1596-1650), the defining scientist, Isaac Newton (1643-1727). In the modern era science was but one manifestation of a new emphasis on objectivity. Philosophers came to believe that genuine knowledge was accessible, valuable not only for its own sake but also as a political instrument. "Knowledge is power", said Francis Bacon.

Modern philosophy was founded on an apparent contradiction: we come to know the world 'outside' by looking 'inside'. Modern philosophy was born of the paradox, objectivity out of subjectivity; the arrogance of knowledge coupled with humble self-criticism. Western modern philosophy is a story of the rise of science, the ennoblement of reason, the pursuit of knowledge, a thirst for power and the power of politics (Solomon, 1996: 175-178).

The postmodern era refers to the social condition that emerged in Europe and the countries of European descent in the 20th century, and took its present shape in the second half of that

89

century. The term 'postmodern' means many things to many people. It is unimaginative, yet appropriate as it draws attention to continuity and discontinuity as two faces of the intricate relationship between the present social condition and that which proceeded it and gave birth to it (Bauman, 1992: 187).

Largely seen as negative, rarely positive, it is the celebration of an ending but not clearly the beginning of something new. It rejects an old, naïve but earnest philosophical confidence and assertiveness for what many postmodernists see as the only healthy intellectual attitude: a vigorous scepticism. It focuses on, even rejoices in, a widespread fragmentation of the world. In fact postmodernism has invited an obscurity and pretentiousness almost unmatched in the long, often obscure, pretentious history of philosophy. Postmodernists take inspiration from the German philosophers Nietzsche and Heidegger and a sequence of briefly fashionable French philosophers such as Sartre and Foucault (Solomon, 1996: 300-301).

The terms 'modern' and 'postmodern' can also refer to a style of thinking or a state of mind. Zygmunt Bauman (1992: xi-xvii) categorizes the modern style as a search for structure and as an abstract and universal rationality in terms of which the world can be understood and controlled. One thinks immediately of Kant's categorical imperative and the universal laws of Newtonian mechanics. Postmodern thinking, without totally dismissing rationality as such, reacts to this narrow rationality and has "an incredulity towards metanarratives" (Lyotard, 1984: xxiv). Or, as George Bernard Shaw put it, "The man who listens to Reason is lost: Reason enslaves all whose minds are strong enough to master her".[25]

The world we live in cannot be described fully in terms of a closed set of rules. It is complex, it is confusing, and it is a mess. Postmodernism recognizes this. It celebrates difference and diversity, but its approach is neither irrational nor relativistic. This is exemplified in the postmodern approach to ethics (Cilliers 2002).

4.4.2 Ethics

What is, ethics? What is morality? Ethics constitues the moral principles governing or influencing conduct. Ethics also refers to the branch of knowledge concerned with such principles. In other words ethics is the philosophical study of morality, the study of the concepts involved in practical reasoning: good, right, duty, obligation, virtue, freedom, rationality, and

choice.[26] Morality is defined as the principles concerning the distinction between right and wrong or good and bad behaviour, or alternatively as a system of moral principles or values.

Thus, the morality of people and their ethics amounts to essentially the same thing. However, there is a usage of the term that restricts morality to systems such as that of Kant, based on notions like duty, obligation, and principles of conduct, reserving ethics for the more Aristotelian approach to practical reasoning, based on the notion of a virtue, and generally avoiding the separation of 'moral' considerations from other practical considerations. The scholarly issues are complex, with some writers seeing Kant as more Aristotelian, and Aristotle as more involved with a separate sphere of responsibility and duty, than the simple contrast suggests.

Questions that arise are: What is 'right' and what is 'wrong'? What is 'good' or what is 'bad'? What is the source of moral authority? According to Wittgenstein, ethics is transcendental. His writings on ethics are a straightforward articulation of the absolute inarticulateness of ethics, but to begin to discuss this will take us into another complex, scholarly issue that is outside the scope of this thesis. Suffice it to say that as a start a good insight to the subject is to be gleaned from William Rasch's paper *Immanent Systems, Transcendental Temptations, And the Limits of Ethics* (2000: 73-98*)*. In it he discusses Wittgenstein's position on ethics and Drucilla Cornell's attempts to construct a 'quasi-transcendental' ethics in her book *The Philosophy of the Limit* (1992). It also discusses the thoughts on morality of the contemporary systems theory sociologist Niklas Luhmann (1985). Luhmann sees the moral code as having detached itself from its pre-modern locus in religion and become a self-replicating 'parasitic invader' of functionally differentiated social systems; although he concedes that, like bacteria in bodies they can be beneficial.

Drucilla Cornell says:

> *For my purposes, 'morality' designates any attempt to spell out how one*
> *determines a 'right way to behave,' behavioural norms which, once determined,*
> *can be translated into a system of rules. The ethical relation, a term which I contrast*
> *with morality, focuses instead on the kind of person one must become in order to*
> *develop a nonviolative relationship to the Other. The concern of the ethical relation, in*
> *other words, is a way of being in the world that spans divergent value systems and*
> *allows us to criticize the repressive aspects of competing moral systems*
> (My underlining).

91

In effect Cornell wants to establish a hierarchical relationship between ethics and morality. Morality, subordinated to ethics, is then equated with the enunciation of behavioural norms and the generation of a system of rules. Over and against morality, ethics would then seem to occupy a transcendental position 'outside' of any articulated moral code.

As Rasch points out, what surveys 'divergent value systems' – ethics – is itself rooted in a value system. The ethical relation dictates that we have a 'nonviolative' relationship to the Other (why?), and we are to criticize the 'repressive' aspects of the moral systems we observe. Both adjectives suggest a moral code: "Thou shalt not violate or repress the Other" (Rasch, 2000: 84). This is an aporia, of which there are many when it comes to ethical issues. So, we are still left with the question of how do we know what is right or wrong? This meta-ethical dilemma will now be addressed.

4.4.3 Postmodern Ethics

The golden rule is that there are no golden rules.
G B Shaw [27]

Modern ethicists argue for universal ethical principles that always apply to everybody, such as Kant's categorical imperative. But, there are problems. With clear formulations one can just about universalize anything. Also such principles tend to be too general, abstract and impractical to provide meaningful guidelines for ethical behaviour in actual everyday circumstances. Indeed, it can be logically argued that a modernist approach is a way of avoiding or, at least, circumventing ethical responsibility. This can result in the rendering of a wide variety of transactions exempt from moral evaluation.

Is one involved in ethical behaviour if one is simply following a set of rules? Just identify the rule and gauge the appropriate response; no moral decision need be made. The individual is not held responsible for the consequences of his or her behaviour. It resides with the legislators and law enforcers. The possible inequities, the violations of justice that can result are frightening and endless. Think of apartheid, think of Hitler's Germany, think of Stalin's Russia.

It is precisely against the blind following of rules that postmodern ethics reacts. For the postmodernist there are no a priori or universal rules that may be used to ensure ethical behaviour under all circumstances. Each situation must be judged on its merits in deciding what action to take. Moral responsibility cannot be avoided. But as Bauman (1992: xxii) describes it there is an, 'ethical paradox of modernity':

> *This is that the postmodern condition restores to agents the fullness of moral choice and responsibility while simultaneously depriving them of the comfort of the universal guidance that modern self-confidence once promised. Ethical tasks of individuals grow while the socially produced resources to fulfil them shrink. Moral responsibility comes together with the loneliness of moral choice.*

Moral responsibility cannot be shifted on to the rule itself, or onto those laying down or enforcing the rules or laws. We always have a choice, even if it leads to breaking the law. Acting ethically and being law abiding are not necessarily synonymous.

On this view, individuals are forced to rely on their own subjectivity whilst being cognizant of the unavoidable relativism of any moral code, the strength of which is determined by the conviction of its followers. Morality is privatized and ethics becomes a matter of individual discretion, uncertainty and risk, without obvious social guidelines or the support of philosophical assurances. The choice must be practical and constructed from first principles derived from the ethical convictions and moral conduct of respectable individuals or groups. The choice is often one between solidarity and indifference.

Behind the paradox lies a practical dilemma. Acting on one's moral convictions embodies a desire for universal acceptance for such convictions, which smacks of previously discredited, rule dominated authoritarian modernism. A Catch-22 situation if ever there was one.[28]

Bauman highlights the effects of two important aspects of postmodernist ethics. The first aspect he terms the plurality of authority. That is, if general rules for ethical behaviour do not exist, rules can be derived from negotiation and competition. Such rules are never more than provisional because unanticipated, contentious issues arise, leading to a need for new rules. The negotiation of rules themselves takes on a distinctly ethical character and thereby moral

responsibility reverts to the individual (agent). Ethical goals are reached through participation in a dialogue, not by listening to a monologue.

The second is the enhanced autonomy of the agent. Self-control, self-reflection and self-evaluation become primary. Without undermining the autonomy of the individual ethical principles are sought which go beyond mere selfish interests. Rather than ethical rules there is a need for ethical expertise, such as can be provided by religious or quasi-religious movements. Also, the enhancement of individual autonomy has the effect that 'battle lines' are drawn between different autonomous agents. For example, to what extent should one allow individuals with different, often extremely unconventional, bizarre or even deviant principles to be autonomous, if there are no fixed criteria against which to evaluate behaviour? The answer is that the principles have to be debated.

In postmodernity ethical problems become a central issue, even though the issues are not new. Moral responsibility and choice reside with the individual, which means that one needs moral competence. This can be gained through the search for as much information as possible, entailing the effective communication of information and principles, albeit in an already information saturated world. People must work together in a responsible way to address differences, resolve conflict and to interpret what it means to lead the good life.

Carl Wellman (1990: 291) has suggested that ethics become practical in the choice situation. "What should I do?" entails considerable investigation and reflection in regard to a particular ethical problem. How does one know which act is right? He proposes that this be determined by weighing the reasons, by weighing the reasons for doing an act against the reasons for not doing it. One must think through the various arguments for and against and feel their logical force or lack thereof. The logically valid argument is the one that retains its persuasiveness. Wellman admits that the logical connection between factual premises and moral conclusion cannot be deductive and, therefore, he calls for a wider conception of reasoning. He believes that logical theory must come to terms with the kind of thinking which, he says, we all adopt when we decide what action is right. (When it come to being enslaved by reason, a fan of George Bernard to be sure).[29]

Cilliers argues that there is something profoundly unphilosophical, if not unethical in proceeding only from practical constraints when determining choices. We are dealing with complex

phenomena and he suggests that we do the best we can each time we have to make an ethical choice or moral judgement (Cilliers, 2002). We follow principles *as if they were universal rules* but we have to remotivate the legitimacy of a rule *each time we use it*. We should gather all possible information and consider all possible options. We then make a decision. However, we have to be prepared to reconsider the choice in the light of new information or additional options, always remembering that the responsibility for the moral judgement, for the choice, remains with the moral agent. Rules may be broken, but breaking a rule does not invalidate it. This would have been the case if the rule were part of an abstract set of rules bound by logical relationships. However, if it is a rule emerging from a complex set of relationships the very nature of such a rule will be the possibility of not following it (Cilliers, 1998: 139). After all, as the well known saying goes "Rules are for the obedience of fools and the guidance of wise men" (source unknown).

For our complex, post modernist world I believe Wellman's approach to resolving moral problems is appropriate provided cognizance is taken of the points made by Cilliers. However, I consider that the resume I have given of postmodern ethics needs to be expanded on in light of a detailed understanding of society as a complex, self-organizing system of which we human beings form an integral part. We can never stand outside of it. Accordingly, I propose that we need an appropriate pluralistic ethics if we are to survive and flourish both in human society and within a complex Gaian world as a whole.

4.4.4 Ethics and Complexity

Leaving aside Gaia and the biosphere for the moment, and concentrating on those systems more specifically relative to humankind I will now summarize the ten characteristics of complex systems developed by Cilliers and summarize his descriptions of both economic systems (1998: 6) and postmodern society (1998: 119-123). From this matrix I have identified certain 'ethical principles' appropriate for one's survival and prosperity in our complex world.

Guided by an understanding of the complexity of the world, and the interacting network of complex adaptive systems of which it is constituted, I will argue for an altruistic virtue ethics centred around and founded on compassion, and in terms of a moral code of practice conducted responsibly and pragmatically. Compassion is an altruistic virtue with which tolerance, patience, and respect for others are compatible human traits. To act responsibly

95

requires knowledge of a situation and the possible future consequences of our actions and decisions. To act responsibly often entails loyalty to others or loyalty to a set of principles.

COMPLEXITY

Characteristic	Economy	Society	Proposed Ethical Principle
1. Large number of elements	Many people	Many people	Compassion, respect, tolerance
2. Dynamic interactions	Lending/borrowing, buying/selling	Human relationships	Trust, honesty flexibility
3. Richly connected interactions	Shops, banks, other people	Diverse: family, friends, bosses, co-workers	As per 1& 2
4. Non-linear interactions	Small investment, large returns	People react differently	Patience, flexibility, responsibility, pragmatism
5. Short range interactions	Local business, internet links	Multiplicity of local groups	Loyalty, cooperation
6. Feedback loops	Good investment, good return	Good behaviour rewarded	Reciprocity, altruism
7. Open systems	Flows through system, e.g. money. Outside interventions: politics	Society in an ecosystem	Flexibility, responsibility
8. Non-equilibrium	Dynamics of supply and demand	Constant change, mass media influence	Flexibility, pragmatism, tolerance
9. History	Today's prices based on yesterday's	Current society a result of past events	Respect, knowledge
10. Ignorance of overall effects	Cumulative effect of individual actions; inflation, interest rates	Society complex, ever changing	Flexibility, responsibility

Figure 12.

What emerges from this exercise is that the principles may be logically arranged to three categories:

Compassion	Responsibility	Pragmatism
Tolerance	Loyalty	Flexibility
Patience	Knowledge	Reciprocity
Respect		
Altruism		

But we have to be practical. There is no all-embracing ethical theory. Aporias in ethical matters abound. Dilemmas are frequent when moral decisions are called for. In the next chapter I will argue for an ethics centred on compassion. At the same time I will also argue for moral pluralism, flexibility, and pragmatism. Pragmatism is necessary if the required flexibility of mind is to be obtained, the readiness to change rules accepted, if individually and as humankind we are to successfully adapt to evolving social and environmental developments and changes.

CHAPTER FIVE

COMPLEXITY ETHICS: A MORAL 'WORLD VISION'

5.1 Moral Pluralism

There is no all-embracing ethical theory. However, the continuous themes of historical theories can contribute to an adequate and comprehensive ethical model. In the pursuit of what is, therefore, moral pluralism it is appropriate to first consider the ethical theories proposed by some of the great philosophers of the past, a methodology adopted by the 19th Century German philosopher G.W.F. Hegel (1770-1831). He insisted that "no philosophy has ever been refuted", only the claims of certain philosophers to have had the last word (Norman, 1998:4). He saw the task of the history of philosophy to be to identify important principles, to allot to them their appropriate place as elements within the whole, and to identify their proper relations to other necessary philosophical principles. Accordingly, in my pluralist approach to arriving at a proposed ethics founded on compassion, (governed by responsibility and applied pragmatically) for living in harmony with others in our complex world, I will adopt a quasi-Hegelian methodology involving the discrimination of the significant and relevant from the insignificant and irrelevant. I will discuss the tradition of the virtues as espoused, by Alasdair MacIntyre, Hegel's ethical philosophy of social relations as interpreted by F.H. Bradley, and McIntyre's arguments for the centrality in well-lived human lives of both virtue and local communities of giving and receiving. Finally I will discuss Arthur Schopenhauer's (1788-1860) ethics of compassion. What I am proposing is a shared vision of basic values for living in a complex world community of life. I have termed this a moral 'world vision'.

5.2 Tradition of the Virtues

MacIntyre in his book *After Virtue* (1981)[30] introduces a troubling suggestion. In our moral practice and language a catastrophe has occurred, he says, one that he likens to a science fiction story where the whole tradition of natural science is destroyed and we are left only with an incoherent fragment. He hypothesizes that the point has been reached where very few realize the nature of the catastrophe. Modern, and for that matter postmodern, moral philosophy is no more than "an unharmonious melange of ill-assorted fragments" (1981: 10) and in his

98

view, in applied ethics, such an ill-assorted melange cannot lead to definite conclusions arrived at by rational consensus. For MacIntyre, any serious work in moral philosophy must be a matter of genealogical inquiry, as it was for Friedrich Nietzsche (1844-1900). What is needed is either to show the way forward out of the unharmonious muddle of modernity of the Enlightenment period, the way of Nietzsche, or backward to the more coherent days of Aristotle (384BC - 322BC) and Thomas Aquinas (1225-1274), the way MacIntrye proposes. That is, back via the philosophy of Aquinas to the *Nichomachean Ethics* of Aristotle and *eudaimonia*, (Gk., happiness, well-being, success, flourishing), the central goal of all systems of ancient ethics.

For MacIntyre, virtues, rules, practices and traditions are all interconnected through the notion of good. He defines a virtue as follows (1981: 178):

> *A virtue is an acquired human quality the possession and exercise of which*
> *tends to enable us to achieve those goods which are internal to practices*
> *and the lack of which effectively prevents us from achieving any such goods.*

The virtues are to be understood as those dispositions which will not only sustain practices and enable us to achieve the goods internal to practices, but which will also sustain us in the relevant kind of quest for the good. By practice MacIntyre means any coherent and complex form of socially established cooperative human activity through which the goods internal to them are realized when attempting to achieve standards of excellence appropriate to them.

Within a tradition the pursuit of goods extends through generations. Hence the individual's search for his or her good is generally conducted within the context of the defined traditions of which his or her life forms a part. The phenomenon of embedding is crucial.

For both Aristotle and Aquinas what indicates and harmoniously relates the goods of particular practices is how well each one supports the greatest good: happiness, understood as human flourishing, understood as the capacity for each particular individual to realize the potential of their generic form. It is further emphasized by Aristotle and by Aquinas that this greatest good is also the common good. It can only be accompanied in the company of others: ethics is inseparable from politics, individual virtues from civic virtues and from tradition-bound practices (Fuller, 1998:8).

What MacIntrye seems to say in *After Virtue* is that the Aristotelian/Thomist (i.e. Aquinas) tradition gives the best, most comprehensive and coherent account of morality so far achieved, at least in the West. MacIntyre's term for Enlightenment inspired views of reason (a belief in shared rationality, capable of progressing towards truth, whether in science or epistemology, ethics or politics) is 'Encyclopaedia'. He maintains it is a myth, that it should rather be viewed as 'rival rationalities', and that premises can only come from experience as it is filtered through such things as prejudice and tradition. It is therefore an illusion to believe that one can reason outside the context of a tradition of inquiry or any specific theoretical point of view (Fuller, 1998: 17-18).

Hegel has importance for MacIntyre's debunking of Encyclopaedia, and for complexity ethics, in that he challenged Kant's idea that his categorical imperatives are inflexible and eternal. He introduced instead the notion that the categories can change and develop and be revised in the light of experience. Schopenhauer is also important. For him, our reason operates as the servant of our bodily needs, our attachment to our survival, our Will to live. As such, reason is unfitted to penetrate the truth about Reality. Next, we come to Nietzsche and his onslaught on Encyclopaedian morals and value. MacIntyre terms Nietzsche's position and genealogical approach 'Genealogy'. MacIntyre agrees with Nietzsche that there is no knowledge that is truly objective and neutral, that is not filtered through a prejudicial perspective, and that different perspectives may be incommensurable and incompatible in terms of such things as meaning, truth, or justification (Fuller, 1998: 21). However, despite seeming to regard Nietzsche as the most consistent modern thinker on morality, he is in no way persuaded be Nietzsche's own moral response based on life-assertion and 'the will to power'.

MacIntyre's intention is to provide a rational vindication of "the moral tradition to which Aristotle's teaching about the virtues is central" (1981: 238). He identifies three elements required for an Aristotelian moral scheme; "untutored human nature, man-as-he-could-be-if-he-realized-his-*telos*[31] and the moral precepts which enable him to pass from one state to another" (1981: 52). Without the second element the whole scheme falls apart. MacIntyre's understanding of a human *telos* is revealed in the following passage:

> *In what does the unity of a single life consist? The answer is that its unity is the unity of a narrative embodied in a single life. To ask 'What is the good for me?' is to ask how best I might live out that unity and bring it to completion. To ask: 'What is the good for man?' is to ask what all the answers to the former question*

> *must have in common. But now it is important to emphasize that it is the systematic*
> *asking of these two questions and the attempt to answer them in deed as well as*
> *in word which provide the moral life with its unity. The unity of a human life is the*
> *unity of a narrative quest (1981: 203).*

MacIntyre does not think that any goal can serve as a '*telos* of a whole human life' but that a genuine narrative quest must be located within specific social practices informed by communal traditions. MacIntyre is aware that thus far there is something excessively individualistic about his account of the virtues, the good life and the human *telos* for he goes on to say that "I am never able to seek for the good or exercise the virtues only qua individual ... am someone's son or daughter, someone else's cousin or uncle; I am a citizen of this or that city, a member of this or that guild or profession; I belong to this clan, tribe or nation" (1981: 204).

MacIntyre places emphasis on the role of *phronesis*[32] in all moral judgement and choice, but one question that MacIntyre does not squarely confront is: how are we to distinguish true or correct narrative histories from those that are only fictions or illusions? MacIntyre tell us that what sustains and strengthens traditions is in part the exercise of the relevant virtues. But there is a danger of a type of romanticism here where we are tempted to think of a tradition as intrinsically good. After all there have been traditions that have been used to legitimate the moral inferiority of the poor, women and minorities. Richard Bernstein (1994: 134-135) suggests that something has clearly gone wrong with MacIntyre's project. Some critics accuse MacIntyre of attempting to synthesize and integrate the incompatible – the typical metaphysical characteristic of Greek philosophical thought with the type of historicism that only makes sense post Hegel. Bernstein on the other hand argues that not only is the disjunction 'Nietzsche or Aristotle?' (the title of Chapter 9 of *After Virtue*) misleading but obscures what in fact MacIntyre has accomplished. Bernstein suggests that we do a grave injustice to the Enlightenment project if we fail to appreciate the extent to which it was a legitimate protest against hypocrisy and injustice. MacIntyre even 'universalizes' the tradition of the virtues on the basis of principles hammered out in the Enlightenment (Bernstein 1994: 137).

There is little in MacIntyre's critique of the Enlightenment that is not stated or anticipated in Hegel. The problem to be confronted is to reconcile two deeply conflicting traditions. It is not clear, even in Hegel's work, whether such reconciliation is really possible. The problem today in our increasingly complex world is how we can live with the conflict and tension between the

'truth' implicit in the tradition of the virtues and the 'truth' of the Enlightenment (Bernstein 1994:140). My argument is that one pursues the route of moral pluralism. Essentially, this is the response of Richard Rorty. His response consists of the following synthesis (Rorty, 1991: 209-210):

i)   Keep what is of lasting value in Encyclopaedia; its stress on individuality, democracy, freedom, equality and tolerance. Dispense with its pretensions to neutrality, objectivity, and truth.

ii)   Keep what is of lasting value in Genealogy; its scepticism and irony, its debunking of Encyclopaedia's myths. Dispense with its excesses such as Nietzsche's Superman ravings.

iii)   Take on board some of what MacIntyre and others, such as Gadamer (Warnke, 1987: 141), have said about the importance of shared practices, traditions and 'solidarity'.

iv)   Put it all in a pot, stir well, and the result will be a coherent philosophy.

Or will it? I have my doubts. Rorty makes it sound all too simple. Nevertheless, the methodology, per se, is not dissimilar to mine in attempting to develop an appropriate and coherent ethics for living in our complex world . But first to Hegel and to his ethics of social relations.

5.3 Socio-Relational Ethics

Hegel's philosophy is notoriously difficult, but one of his foremost interpreters, F.H. Bradley *Ethical Studies* (1876) is eminently readable and it is to Bradley that Richard Norman turns to for his chapter *Hegelian Ethics: Self Realization,* in his book *The Moral Philosophers* (1998). Hegelian morality stresses the social character of the individual, and finds the content of moral life in the actions that derive from particular social relations and functions.

It is a biological fact that the human child is born into and nurtured by some kind of family, which itself exists within wider social groups. One comes to understand who one is, as an individual, by understanding the relations in which one stands to other people, the responsibilities these carry with them, and by acquiring the habits and customs of one's community, through which these relations are understood (Norman, 1998: 113). Friendships and loyalties to other individuals defines one's identity and gives one's life meaning. As Bradley would have it, my self

is "penetrated, infected, characterized by the existence of others, its content implies in every fibre relations of community."[33] This not to say that when one acts on the basis of certain loyalties to others one does it to retain one's sense of identity. Rather it is that one's relations to others are <u>part</u> of ones identity, part of what gives meaning to one's life, and therefore finds expression in one's willingness to devote one's self to their concerns (Norman, 1998: 120).

Bradley is aware that this Hegelian position has its problems and limits: there are aspects of one's life that does not derive from membership of any social society, and that one's community may be confused or rotten. However, I do not see this as a problem per se. For me the important word in the above is 'part'.

An important aspect of Hegelian ethics is 'self-realization', commonly implying realizing one's potentialities. For Bradley this is not so much the distinctively human self, that would take us back to Aristotle, but the social self. In any event, there are problems with self-realization as a foundation for ethics. Rather, Norman suggests (1998: 123), there are important insights conveyed by the concept:

i)   The need for coherence. One may have achievements and ambitions that do not hang together, that one's life lacks any overall shape or meaning, *the unity of a single life*. One needs some dominant concern (*telos*?) not necessarily all embracing but possibly the centre around which everything else organizes itself.

ii)   The need for identity, for which there are two important pre-conditions: the need for recognition and the need for self-expression through work. (The Kantian idea of persons as ends in themselves.)

iii)   The need for activity. Closely connected with the previous point regarding work is the idea that human beings cannot derive full satisfaction from life purely from passive enjoyment. We need to make full use of our faculties to make life genuinely rewarding.

Norman argues, and I concur, that recognition of the social nature of the self constitutes Bradley's (and by implication Hegel's) advance on Hume, Kant and Mill enabling him to provide a more satisfactory account of altruistic concern for others. His 'social relations' approach then leaves us with the question: can we justify not only specific concerns stemming from specific relations to others, but a concern for the needs for all human beings, indeed all living things, the biosphere, and Gaia itself? I not only believe we can but because of the complex

inter-relationships of our world I have no doubt that our very survival *qua* human beings depends on it.

5.4 Animal Nature and Dependency

In his book *Dependent Rational Animals, Why Human Beings Need the Virtues* (1999) MacIntyre makes a sustained argument for the centrality, in well-lived human lives, of both virtue and local communities of giving and receiving. He criticizes mainstream Western ethics, including his own previous position for not taking seriously enough the dependent and animal sides of human nature, thereby overemphasizing the powers of reason and the pursuit of autonomy. Vulnerability makes dependence an unavoidable element of human existence. He maintains that philosophical fantasies arise because we ignore these two connected features of our lives, namely, our animal natures and our vulnerability. He takes issue with the view that our relation to our biological nature is 'external and contingent' in a way that permits a single sharp line to be drawn between human beings and members of the non-human community. As regards our constant vulnerability he points out that at some times in our lives all of us are dependent on the free care and concern of others, and at all times of our lives we could suddenly be catapulted into such dependency.[34]

5.5 Developing a Moral 'World Vision'

One's conception of the meaning of one's life is essentially what MacIntyre refers to as a 'narrative', the story, of one's life, a unifying coherent pattern, in which the elements of one's life fit in order to make sense of the whole. Possibly MacIntyre's focus is rather too much on the self, whereas what is needed is the idea also of a conception of one's world and one's place in it. In other words, a moral vision of the world shaped by one's experiences (Norman, 1998: 213). It must have place for a conception of:

i)   What makes for a worthwhile and fulfilling human life.
ii)   One's relations with and responsibilities to other human beings, not only particular others but also social groups, and humankind in general, including past and future generations.
iii)   One's relations with and responsibilities to the natural world, including all living beings, both sentient and otherwise, and to non-living entities.

104

One's understanding of the world is an understanding of its complexity, of the complex adaptive systems of which it is constituted. On the human level one's identity is a social identity and the network of social relations and dependencies which make up one's life necessarily carries with it ethical commitments and loyalties. In the wider natural world, the biosphere, Gaia and all that exists and lives therein, as a species at least we also have a similar identity and a network of connections, relations and dependencies which make up our lives. Again, necessarily these carry with them ethical commitments, even loyalties. Much of our moral life is in fact made up of loyalties and commitments.

Altruistic concern for others is at the heart of most conceptions of morality. The golden rule *Do unto others as you would others do unto you* comes from the Bible, Matthew 7, verse xii, but in some format it is found in most religions. After all it is logical, even from the point of view of egotistical enlightened self-interest. Apart from a few hermits, we live in societies whether we like it or not. When, altruistic concern, when tolerance, respect and compassion for others breaks down the result is the often horrendous conflicts and abuses wreaked by humans on humans, humans on animals, and humans on the environment. We coevolve and thrive when we extend goodwill towards others with honesty, humility and the sincere desire to help and support others. We reap what we sow. It is that simple, even in a complex world.

A necessary component of one's moral thinking is the conception of a worthwhile and fulfilling life. Fundamental human needs include the need for a coherent identity, recognition, meaningful work, autonomous agency (freedom), emotional balance and mutually supportive relations with others. None of these can be sustainably satisfied without concern and compassion for others. As Axelrod's studies of the game Prisoner's Dilemma illustrate (4.3), whilst cooperation can emerge even among egoists without central authority, when people actually do care about each other and the benefits of reciprocity are understood, the degree of cooperation is increased and its evolution and dissemination through a system speeded up. This is the phenomenon of one person's utility being positively affected by another person's welfare. Thus, altruism is a motive for mutually beneficial cooperative behaviour.

One's relations with others underpin a concern for the needs of others. We are interconnected within the system, be it a social system an economic system or an ecosystem. The interplay goes both ways: certain kinds of relations with others contribute to meeting one's own needs,

and in interacting in a mutually beneficial positive way the system itself will self-organize, evolve and be improved if the behaviour patterns are altruistic rather than egotistic.

Our lives are enriched by cooperation with others and the satisfaction of shared endeavour, by friendships, and by love and devotion. It is these kinds of connections that contribute to one finding meaning in a life that is finite. Our identification with the aspirations of others who will live on after we are gone, our membership of communities which will continue into the future can give us purpose, a *telos*. But altruism can only appeal to people who have experienced what it is to feel love and devotion, "authentic and spontaneous concern" for others, says Norman (1998: 220), which must account for 99.9% of people at sometime in their life. He goes on to suggest, and I agree, that everyone whose life is embedded within a network of relations with others, who is sensitive to the joys and sufferings of others, can come to see that his or her life is impoverished if these feelings and relationships are pushed to the margins of his or her life by ruthless personal ambition, or by attitudes of resentment. Again, these sentiments are supported by Axelrod's insights from studying the Prisoner's Dilemma.

A life shared with others and in harmony with others is thereby made more fulfilling. And the others should not be confined to human beings only. It should include all sentient beings, all living things and even the inanimate world. After all, there is intrinsic value and aesthetic value in inanimate objects. And our vulnerability arising from our dependency as human beings is not only a dependency on fellow human beings, but on other living things, on the ecosystem, the biosphere and Gaia herself. It is only the nature of the relations that change, as they also vary within human society. We are individuals, independent agents, and participants in many complex systems both human and natural, often stacked hierarchically one inside another, like a set of Russian dolls. The external environment of one complex system may be the very body of the next. Alternatively, one complex adaptive system may be no more than an agent within another system.

Bearing in mind the complexity of our existence, our connectedness to 'others' and our dependency on others as rational animals we human beings need the virtues if we are to survive and flourish. For me the virtue that should be the foundation stone of our ethics and the overriding guiding principle of our moral behaviour is that of compassion. But, it must be stressed that is not to deny the importance of other virtues and of other ethical principles. Provided we behave responsibly and are flexible and pragmatic most ethical problems should

be solvable. It is a question of fitness, of deciding on what is the appropriate ethical principle to adopt and what action to take in the specific situation that arises. One has individual moral choice but with it goes responsibility. One weighs the arguments for and against and does ones best, based on the information available (and in terms of which there is a responsibility to ensure that one has the best information available). From experience over time one will learn what is the most appropriate ethics for the particular society or system in which one is living or functioning. Coherence and flexibility do not have to be incompatible.

There will be times when it will be impossible to be compassionate, and/or responsible and/or pragmatic, at the same time. The most successful strategy for sequential Prisoner's Dilemma games is TIT for TAT, a strategy of reciprocity, a 'carrot and stick' approach which is not always being compassionate. However, over time altruistic behaviour wins out in the end, as other players in the game learn what is happening. And so it is in life. Compassion does not mean being meek. Hard decisions have frequently to be taken, leading to some inevitably suffering in the interests of the greater good. It is impossible at all times to be all things to all people. Being pragmatic, may even mean that the most responsible course of action to be taken results in compassion having to be put on one side, at least for a while. If everyone always acted with responsibility and with compassion the world would be a better place. But they don't and they won't, hence the success of TIT for TAT. That does not mean that we should change our ethical principles, for it is those principles that we want others to copy so that in the game of life there is a better outcome for all, as it is for the Prisoners.

Ethically the present urgency is to start thinking within the context of the whole planet, the integral community of a complex Earth with all its human and other-than-human components. The basic ethical norm should be the well-being of the total world community and the attainment of human well-being within that comprehensive community (Berry T., 1999: 105). We need new attitudes, a new ideology even. "At this juncture the choice is not one of science but of ideology" (Berry B., 1988: 223).

"Undoubtedly science has made a major contribution to human civilization but science cannot answer every mystery of nature. It lacks the motivational force to nourish vital qualities like courage and compassion" (Hayden, 1996: 230). We have extracted ourselves technologically and emotionally from our ecological base. We have developed societies that are not integrated with the Earth or with each other. As a world, we are fragmented into competing nations, ethnic

107

groups, and corporations. We are not unified, and to be so will need "empathy, compassion, interconnectedness, and vision" (Earley, 1997: 327). However, this does not mean losing our cultural diversity and therein lies a paradox and a challenge.

The interwoven challenges of the 21st century, human and environmental, will be many and complex. My thesis is that they can be most successfully dealt with if we adopt an ethics based on universal compassion for all living things, a global responsibility for the integrity of the Earth and pragmatism in addressing the complexity of both human and environmental issues and values.

5.6 Compassion

The basic aim of my explanation is to show that by nature we are compassionate, that compassion is something very necessary and something we can develop. It is important to know the exact meaning of compassion. The Buddhist interpretation is that genuine compassion is based on a clear acceptance or recognition that others, like oneself want happiness and have the right to overcome suffering. On that basis one develops some kind of concern about the welfare of others, irrespective of their attitude to oneself. That is compassion.

The Dalai Lama[35]

What do we mean by compassion? The Oxford dictionary definition is: sympathetic pity and concern for the sufferings or misfortunes of others. Pity in English is often associated with condescension, which is not intended here in the context of compassion as a foundation for ethical behaviour. However, goodwill, consideration, sensitivity, benevolence and unselfishness certainly come into the picture,[36] as do honesty and humility.

As to the question of to whom or to what should compassion be extended to, this has already been touched on. Certainly to all other human beings, especially the poor without whose upliftment saving the Earth will be a futile task. But should all forms of life be included, and then if so, by extension, what about the total biosphere? If moral consideration were restricted to humans then the non-human world would have to be considered as having only instrumentalist value, which I propose is unacceptable. I concur with Buddhist thinking, Jeremy Bentham,[37] Arthur Schopenhauer (1839), Alasdair MacIntyre, Peter Singer (1975) and many others that

moral consideration, and hence compassion, should be extended to all sentient beings at least; that is to any entity that seeks pleasurable states of being and therefore seeks to avoid pain.

I would go further. We live in a world that constitutes one large complex adaptive system, Gaia, where the future and well being of all living things is inextricably linked. The interdependence and symbiotic relationships between life forms, and the dependence of all living things on the inanimate constituents of the biosphere as a whole, means that we have ethical responsibility towards the non-living world, even if the basis of such an ethic is not compassion *per se*. This arises both out of the intrinsic worth of nature and our own enlightened self-interest.

The virtue ethic of compassion is found in the great spiritual traditions of humankind, epitomized by such outstanding figures of our world history as: the Buddha, Lao-tse, Jesus Christ, St Francis of Assisi, Arthur Schopenhauer, Albert Schweitzer, Mahatma Gandhi, Chief Seattle and Chico Mendes. They exemplify the ethic of universal compassion together with that of responsibility striving for solidarity and reverence among all beings and not simply human gain. The guiding principle of compassion is "Good is whatever preserves and promotes all beings in their dynamic equilibrium, especially living things, and amongst living things, the weakest and most threatened; evil is whatever harms and does away with beings or destroys the conditions for their development" (Boff, 1997: 136)

The first of the great Western philosophers of the modern era to found his moral theory on feelings rather than reason was the Scottish philosopher David Hume (1711-1776). He thought that we admired the virtues because it was a part of being human to feel sympathy and humanity (Norman, 1998: 55). He wrote:

> *So far thinking that men have no affection for anything beyond themselves,*
> *I am of the opinion that tho' it be rare to meet with one, who loves any single*
> *person better than himself: yet it is rare to meet with one, in whom all the*
> *kind of affections, taken together, do not overbalance the selfish.* [38]

When it comes to compassion as a basis of morality in the Western tradition it is the German philosopher Arthur Schopenhauer to whom we must turn. Of the major figures in Western philosophy Schopenhauer was the first to have a deep understanding of Eastern philosophy and to draw connections between Eastern and Western thought. Perhaps, therefore, it is not surprising that there are similarities in his thinking and Buddhism. Although it would be a

mistake to suppose that Schopenhauer's philosophy was formed to any decisive degree under the influence of Eastern thought (Magee, 1997: 340), in both Buddhism and in Schopenhauer's philosophy there is agreement that, in their inner nature, all living things are one. It is the explanation of compassion as the foundation of morality: in hurting any living thing I am damaging my own permanent being; thus wrongdoing is its own punishment. It would be agreed too that happiness is not to be found in attachment to the things of this world but, on the contrary, in detachment from them, which means the overcoming of desire and the will. Thus, asceticism is held in high esteem (Magee, 1997: 342). In today's environmentally troubled world where the dependence of each human being extends beyond the narrow real of human society all three of these common premises are good reasons indeed for considering Buddhist tenets and the moral philosophy of Schopenhauer when seeking a foundation for ethics.

Schopenhauer's primary ethical treatise was his essay *On the Basis of Morality*, written in 1839. It presents a descriptive ethic radically at odds with rationally based, prescriptive ethical theories. It contains a wide-ranging critique of Kant's ethics and argues that compassion is the basis of morality. In so doing it presents a virtue ethic in which passion and desire are viewed as the keys for explaining different moral behaviours and worldviews (Cartwright: 1995). Although his metaphysics is Kantian, he is critical of much of Kantian ethics, particularly as it relates to animals.

Schopenhauer describes a number of features any account of the basis of morality must possess. It must show that the basis of morality is empirically discoverable as something lying intimately in human nature; it must explain why humans have incentives sufficient to overcome the egotistic tendencies that dominate human behaviour, and it must be free of theological assumptions. His fundamental moral principle was "Neminen laaede, imo omnes quantum potes, juva" or: "Injure no one: on the contrary, help everyone as much as you can."
(Payne, 1995: 92).

Schopenhauer recognizes three classes of actions to which different moral values are attached. Some actions are morally reprehensible (*moralisch verwerflich*); some possess moral worth (*moralischen Wert*); and some are morally indifferent (*moralisch indifferent*), neither reprehensible nor worthwhile. Schopenhauer claims that all human actions are intentional, having as an ultimate end something that is either "in agreement with or contrary to a will" (Payne, 1995: xxiv). Since Schopenhauer construes weal (*Wohl*, well-being) and woe (*Wehe*,

110

misfortune) as signifying, respectively, those things in agreement with a will and those things contrary to a will, he views all action as ultimately referring to someone's weal or woe. Because an agent's action may have as its ultimate end the agent's or another's weal or woe, Schopenhauer recognizes four ultimate ends for human actions, although he only describes three in *On the Basis of Morality*.[39] These three ultimate ends become the three basic incentives for human action. They are: egoism (*Egoismus*), which desires (*will)* the agents own weal; malice (*Bosheit*), which desires another's woe; and compassion (*Mitleid*), which desires another's weal.

Schopenhauer believes that most humans are susceptible to each of these incentives in varying degrees, and he also claims that all incentives and motives can be reduced to these three operating either alone or in combination. Then by drawing upon past argumentation, and by an argument by elimination, Schopenhauer concludes that compassion is the source or basis for actions of moral worth; that egoism is the basis of morally indifferent actions; and that malice is the basis for morally reprehensible actions.

Schopenhauer must have realized that readers would find it difficult to view compassion as the sole motive for morally worthwhile actions. Although compassion may be the source of some of these actions, it is difficult to imagine that it is the source of all such actions. Traditionally, and this is Schopenhauer's view, compassion is viewed as a response to another's misfortune, and that it is by relieving this misfortune that the other's well being is promoted. Yet it is also true that another's well-being can be promoted in ways not directly related to relieving or preventing another's misfortune. Schopenhauer appears to anticipate this challenge by arguing for the counterintuitive claims that (i) our sympathies are usually restricted to another's suffering and that we are relatively indifferent to another's enjoyment; and (ii) pain and suffering have a different ontological status than pleasure or happiness.

Schopenhauer argues that in feeling compassion for another "I suffer directly with *him*, I feel his woe just as I ordinarily feel only my own; and likewise I directly desire his weal in the same way I otherwise desire my own" (Payne, 1995: 143). Compassion, he holds, involves "the immediate participation independent of all ulterior considerations, primarily in the *suffering* of another, and thus in the prevention or elimination of it; for all well being consists in this" (Payne: 1995: 144).

By experiencing another's suffering like their own Schopenhauer contends that compassionate agents are moved to treat this suffering as if it were their own; they act to prevent or relieve it, to secure the other's well being just as they would their own.

Schopenhauer contends that compassion cannot be explained psychologically. He calls it the "great mystery of ethics" (Payne: 1995: 144). As such Schopenhauer views compassion as an ethical primitive or basic principle of explanation. Compassion is the ground or basis of actions of moral worth. Appealing to compassion explains morally worthwhile phenomena, and no other ethical phenomena can be used to explain compassion. Therefore, according to Schopenhauer it requires a metaphysical explanation (Cartwright, 1995: xxiv-xxvii).

In addressing himself to the mystery of how the occurrence of compassion is possible Schopenhauer tells us that empathy and compassion are made possible by the fact that each of us is, in his innate nature, at one with the noumenal, and that the noumenal is one and undifferentiable; therefore all of us (sentient beings) in our deepest nature, are one with another, are undifferentiable from each other. Thus, he says, in my innermost recesses I am not merely similar to other beings, it is merely on the surface that similarity appears: at the very bottom they and I are literally one and the same thing. "Only as phenomenon is the individual different from the other things of the world; as noumenon he is the will that appears in everything"[40] (Magee, 1997: 199). Perhaps another way of putting it would be that we are all components that go to make up a single complex system, the noumenon, in the same way that one of the cells in my body is similar to millions of others. At the very bottom they are one and the same thing, me. Without me they cannot exist.

The fact that all beings are phenomenal manifestations of an undifferentiated One means that in the ultimate ground of our being we are identical. Hence, this explains compassion; our propensity to identify with other sentient beings to feel with and for them, which if we were ultimately separate would either be inexplicable or mistaken. Consequently, it is compassion, not as Kant would have it, rationality, that is the foundation of ethics (Magee, 1997: 453).

In his book *Dependent Rational Animals, Why Human Beings Need the Virtues* (1999), Alasdair MacIntyre argues two points. The first is, that in our own beginnings as rational agents we were very close to the condition of other intelligent, but non-language-using species, such as dolphins; that our identity was then and remains an animal identity; and that we are right to

112

ascribe to at least some of those species intentions and reasons for action. The second is an emphasis upon the vulnerability and disability that can pervade human life, and the extent of our consequent dependence on others.

He then attempted to answer the question of what it would be for such vulnerable and dependent rational animals to flourish. He deduced that we need both those virtues that enable us to function as independent and accountable practical reasoners and those that enable us to acknowledge the nature and extent of our dependence on others. Both the acquisition and exercise of those virtues are possible only in so far as we participate in social relationships of giving and receiving (MacIntyre, 1999: 155-156). One of the virtues he refers to is *misericordia*, that is the virtue of taking pity, or according to Thomas Aquinas, grief or sorrow over someone else's distress, just in so far as one understands the other's distress as one's own (MacIntyre, 1999: 125). This is the same as Schopenhauer's compassion.

MacIntyre cites two examples of 'compassion' from very different cultures:

From the Greek, when according to Sophocles, a shepherd was given the task of killing Oedipus, he was instead moved by pity to dangerous disobedience and secretly entrusted the child to another shepherd.

From the Chinese, when Mencius said that "all human beings have the mind that cannot bear to see the suffering of others…when human beings see a child fall into a well, they all have a feeling of harm and distress" and this is not because they think it will gain them credit with others. What they will lack, if they do not respond to the child's urgent and dire need, and just because it is an urgent and dire need, is humanity, something without which we will be defective in our social relationships (MacIntyre, 1999: 123).[41]

The central teaching of Buddha was that suffering could be transcended. Suffering was the key problem for human beings, because all life is transient, ending in pain, loss, and death. The cause of this suffering is the craving that arises from consciousness of ourselves as lonely and isolated egos in the universe. Ridding ourselves of this craving is possible if human beings could clear their minds of greed, hatred and delusion. This could be accomplished by focusing on an eight-fold path of understanding, speech, mindfulness, action, livelihood, effort, attentiveness, and meditation. A life thus led became one of compassion. Like Jesus Christ, The

Buddha embodied compassion as a response to suffering and injustice. And, although both Christianity and Buddhism became primarily human social philosophies, their moral axioms can be extended to nature. It can be certain that both these great teachers would have done so in today's world.

In Buddhist teachings there is an admonition to practise 'kindness and pity to <u>all</u> living beings'. Usually this has been restricted to sentient beings, but some Buddhist teachers have expanded the concept to the whole of nature by the claim that what is not sentient is inextricably bound up with what is sentient and alive. This is what Zen poet and ecologist Gary Snyder (1995) means when he says that compassion for suffering lives must be extended to the suffering of natural systems. Thich Nhat Hanh, an exiled Vietnamese monk with a large Western following emphasizes the precept "to cultivate compassion and learn ways to protect the lives of people, animals, plants, and minerals".[42]

The key difference between Western and Eastern thought has been that the first is premised on nature as an outside force to be dissected, while the latter 'goes with the flow' of nature. Buddhism assumes an interdependent universe based on energy flows, much like the universe imagined by modern complex systems theory and the new physics. Everything exists in a state of what Thich Nhat Hanh calls tiep hien, meaning 'interbeing':

> *Without all of the non-flower elements – the sunshine, the clouds, the earth,*
> *minerals, heat, rivers and consciousness – a flower cannot be. That is why*
> *Buddha teaches that the self does not exist. What we call 'self' is made only*
> *of non-self elements.*[42]

Sixth century Buddhist philosophers argued with farsightedness that:

> *when we speak of all things, why should exception be made in the case of*
> *a tiny particle of dust … there is no water without waves; there are no waves*
> *without wetness … there is only one undifferentiated nature.*
>
> (Hayden, 1996: 166-170).

It is interesting to note that one of three eminent German philosophers of his time whom Schopenhauer held in contempt, and towards whom he was even abusive, was Friedrich Schelling (1775-1854). (The other two were Fichte and Hegel). Schelling came in for the least abuse and begrudgingly Schopenhauer spoke favourably of his main work *Naturphilosophie* or

114

Ideas for a Philosophy of Nature. Schelling depicted the totality of what exists as something that is perpetually evolving, and is therefore to be understood only in terms of the direction that its evolution takes. And the direction it takes is towards an ever-increasing self-awareness. Since it is the totality of what exists that is involved in this progress, the whole of reality can be viewed as one single developing organism. The most significant steps in the progress have been, first, the emergence of organic out of inorganic nature, and then, within organic nature, the emergence of man. The point to be stressed here is that it is within the natural world that man has come into existence, and developed, and he remains inextricably interwoven with it: he is of one stuff with it. He is literally spiritualized matter. So the human spirit having emerged by imperceptible degrees within the material world, can be regarded as the inner essence of that world rendered conscious; Spirit is invisible Nature. Therefore Nature must be visible spirit. The two are, in the depths of their being, one. Any view of reality which polarizes them is mistaken (Magee, 1997: 281).

What is amazing about Schelling's *Ideas for a Philosophy of Nature* is that it was first written twelve years before Charles Darwin was born, (and about 140 years before James Lovelock and Stuart Kauffman!). It could be claimed that 'complexity science' has a much longer history than many at the Santa Fe Institute think. But in Schelling's day it was called 'Philosophy'.

Schelling's philosophy, which was the earlier of the two, has a number of striking similarities with Schopenhauer's:
(i)   Schelling saying that Nature is visible Spirit accords with Schopenhauer saying the phenomenal world is the perceptible world of the noumenal. Both see:
(ii)   The phenomenal world as essentially evolutionary and the driving force as not rational or mental.
(iii)   The goal of the process as self-awareness.
(iv)   Man as having been produced in order to serve the ends of the process.
(v)   An identity of inner nature between man and the natural world.
(vi)   Creative art as one of the highest human activities, looking into the ultimate nature of what is.

If Schellings's philosophy of Nature has striking similarities with Schopenhauer's philosophy, and if Schelling's ideas accord closely with those of present day researchers in biological evolution and the complexity of our natural world, and if Schopenhauer founded his ethical

theory on compassion, can we then infer that compassion is the correct ethics for our complex world? I would like to think so, but I would hesitate to claim this argument logically proves it!

Buddhist writings, together with the work of Schopenhauer, Schelling, Hegel and MacIntyre, convince me that compassion is the correct foundation for ethics in a complex, postmodern world. What comes out in the writings of all of them is the 'oneness' and connectedness we as human beings have with other sentient beings, indeed all life forms and all natural phenomena.

We share a common destiny with our co-members of the biotic community. We have a responsibility to act out of compassion for them. In preserving the environment we will be contributing to the achievement of our good, *qua* human beings. We should also have compassion for the poor, oppressed and excluded members of our own human species and respond to their urgent and dire needs. We shall be defective if we do not. Saving the Earth entails saving the poor. We all share a common destiny.

5.7 Responsibility

> *A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong if it tends to do otherwise.*
>
> *(Leopold, 1949: 224-225)*

This is what J. Baird Callicott (1989) calls the 'summary moral maxim'[43] of Leopold's Land Ethic. It capsulizes beautifully the moral responsibility we have to the biotic community and to the Earth as a whole. Interestingly, it accords closely with Leonardo Boff's guiding principle for compassion (4.5.6). It would make good sense even if one was thinking only of human social systems per se, and reworded it to read "… integrity and stability of the community". From a complexity viewpoint, whether biotic community or human social system, it could be argued that the word 'stability' is inappropriate. After all, complex adaptive systems operate best in conditions far from equilibrium. The counter argument would be that the word 'tend' is all important. Keeping the system out of the too ordered, 'dead' state, but not in chaos.

Human activity has inflicted severe and often irreversible damage on the environment and on many of the Earth's resources that are critical to life. We have a responsibility to slow down, halt

and ultimately reverse the degradation, and at times devastation, we have been and are still inflicting.

This will entail a great deal of innovation and courage in the social, economic and scientific arenas of our human endeavour. Fundamental changes in the way we connect to and interact within our human societies and in the natural world are urgent, and the way we think about it, but it would be irresponsible and naïve to expect and to wait for any miraculous scientific solutions.

> *I find it hard to see a success of any scientifically-guided environmental*
> *management without a concurrent personal commitment motivated by moral*
> *obligations of responsibility and by willingness to share and to sacrifice.*
> *Science is no substitute for morality, and to believe that the ethics of limits*
> *and sharing has no place in dealing with our environmental dilemmas would*
> *be to forfeit any hope for real successes in solving them.*
>
> *Vaclav Smil*[44]

Smil joins the chorus of the many, including the Union of Concerned Scientists (UCS)[45] who for the last ten years now have been calling for a new ethic, a new attitude of responsibility for caring for the Earth and for ourselves. We must all recognize the fragility of the biosphere and no longer allow it to be ravaged. This ethic must motivate a great movement, convincing reluctant leaders, reluctant governments and reluctant people to effect the needed changes. (VanDeVeer, 2003: xxix).

Courage and conviction, compassion and wisdom will be the attributes called for of world leaders if they are to responsibly carry out their duty of stewardship towards the Earth, and life on it. Our societies must be managed as never before in terms of new ecologically founded economic and accounting standards commensurate with enabling us to sustain and enhance the flourishing of all life, human and non-human.

> *As for those who would take the whole world*
> *To tinker it as they see fit, I observe that they never succeed …*
> *For indeed there are things*
> *That must move ahead,*
> *While others must lag …*

So the Wise Man discards
Extreme inclinations to make sweeping judgements …
Lao Zi, Dao De Qing[46]

In order to preserve the biosphere capable of sustaining life in a manner that we know and desire calls for management of the Earth on a global scale. Whether we like it our not our past irresponsible tinkering, our destruction and impoverishment of numerous ecosystems through exploitive and polluting industry has earned us that responsibility.

The challenges are complex and ever changing. The solutions will be too. What is needed is the thoughtful and relatively speedy development of measures to restrain the growth of affluent consumption, and measures which would enable the poor of the world to improve their quality of life to dignified levels with the minimum possible environmental impact. Essential will be the real pricing of commodities to incorporate contingent environmental cost factors. We need more responsive and responsible local and national institutions. We need a genuine commitment to effective international co-operation. Then, together with the adoption of consensual management methods, this would offer a pathway towards drastically reducing excessive consumption, and concomitant polluting wastage, and the employment of efficient production and distribution systems (Smil, 1993: 109).

Nevertheless, we must never lose sight of the wide range of scales for effective strategies. Global approaches to problems are often necessary and useful, "yet too often those who seem to be acting as the guardians of the whole civilization are just privileged providers of abstractions and generalizations which will do nothing to affect realities. Merely acknowledging local, regional and national differences and peculiarities is not enough: they will have to be at the core of effective control or management designs" (Smil, 1993: 110-111).

The proven utilitarian success of modern science and free enterprise has been shown to be fundamentally destructive. Accordingly, it must now be governed by the humility of a grander perspective. So called Western civilization has had an immense global influence and it is, therefore, the developed countries that have an overriding responsibility to take the lead in laying the foundations of a new world order, a new world civilization (Smil, 1993: 212). The rich countries have this special responsibility because it is the actions of these countries that will set the tone for the future.

118

The most important attribute of Western democracy that must be preserved in order to succeed in the challenge is its heritage of freedom, dissent and choice. Profound scepticism, sustained inquisitiveness and non-circumscribed criticism are the best possible protectors of flexibility, without which there will be no viable adaptation and no long term survival. Civilizations are complex interactive systems, able to adapt. The challenge is to minimize the negative mutually reinforcing threats of population, poverty, and greed, and maximize the capability of adaptive responses of social and technical innovation.

Nothing is more important than opting for flexible strategies derived from vigorous free dialogue. It is still the best-known self-correcting adaptive arrangement of human society. We have to resist sweeping normative solutions, no matter from which part of the ideological spectrum they come. There is no single-vision salvation. Dogmatic commitments will make it much more difficult to accommodate unforeseeable changes. To avoid inflexibility and simplification we have a responsibility to engage in the vigorous exchange of ideas. Flourishing in free societies, such dialogues, although they can be laborious and discordant, frequently translate intellectual flexibility into practical actions and create futures that even the best minds are unable to visualize (Smil, 1993: 214).

5.8 Pragmatism

Things want to tell us something but … they are unable to find a single mouth to speak a single language.
  Ramon Gomez de la Serna [47]

Ethics has had a tendency to become mired in long-running theoretical debates. Arguments for or against a particular ethical position can easily be constructed so as to be logically valid. Conclusions following premises. But rival premises are such that we possess no strictly rational way of weighing the claims of one against another. Arguments become a matter of assertion and counter assertion (MacIntyre, 1981: 8). Hence the shrill tone of much moral debate.

Our world problems are complex. By implication and of necessity so will be our solutions. We should do the best we can each time we have to make an ethical choice or moral judgement, gathering all possible information and considering all possible options. And we have to be

prepared to reconsider choices in the light of new information or additional options. We have to be flexible. We have to be pragmatic.

What is called for in applied ethics again takes us back to the *Nicomachean Ethics* of Aristotle and the intellectual virtues of *episteme*, *techne* and *phronesis*. *Episteme*, from which the word epistemology derives, can be regarded as universal or scientific knowledge. *Techne*, from which the word technology is derived, concerns bringing into being something that was not. *Phronesis*, with no direct modern derivative, is a virtue related to value rationality and *praxis*. It equates to practical wisdom or moral knowledge. In addressing our global challenges we shall need all three of the virtues of *episteme*, *techne* and *phronesis* … founded on an ethic of *misericordia* (compassion*) and respondere (*responsibility*)*.

Phronesis requires experience and practical common sense (Flyvbjerg, 1993: 12-14). Virtue, according to Aristotle, consists in observing the mean between excess and deficiency in accordance with reason; his famous 'Doctrine of the Mean'. This does not entail always following a middle road but entails having feelings on the right occasion, for the right reason, to the right degree, and towards the right person. But how does one determine where the mean lies? In the way that a prudent person, a *phrominos*, a possessor of practical wisdom would. That is, through phronesis (Norman, 1998: 39). A complexity theorist would be satisfied. Strictly applied rules can lead to authoritarianism; too much freedom, anything goes, to anarchy. We need order in the world but we also desire liberty. Phronesis can help us self-organize and ultimately flourish by putting us on the middle road, even though it may twist and turn.

From Aristotle's virtue concept of phronesis Bent Flyvbjerg has identified characteristics that he considers are crucial to the development of applied ethics. Amongst these are:

(i)   The importance of what is particular. Context-dependency is emphasized over universality.

(ii)   The importance of what is concrete and practical rather than what is theoretical.

(iii)   The power of example, particularly examples that are specific and fundamental to the way human beings function.

All are important when considering ethics in our complex postmodern world.

According to Aristotle phronesis concerns "action with regard to things which are good or bad for <u>man</u>" (Flyvbjerg 1993: 14, my underlining). In applying this globally it should be extended to include the <u>biosphere and all living things</u> … which accords with the 'summary moral maxim' of Aldo Leopold (5.7). An approach based on pragmatism should incorporate and be consistent with the postmodern approaches proposed by Wellman and Cilliers (4.4.3).

Compassion, responsibility and pragmatism. Wisdom, knowledge, technical and social innovation. Or in the words of the Ancients: Misericordia, Respondere and Pragmatica. Episteme, techne and phronesis. Armed with these virtues and principles are we prepared to make the sacrifices, and do we have the courage, to take on the great challenges of our time? All living beings, humans rich and poor, all other forms of life, sentient or not, depend on humankind rising to them. Future generations are depending on us. They are our children and grandchildren. They will suffer if we fail. Let us show them compassion. We have a responsibility to do so. We can do so. Universal human flourishing is not only attainable but also sustainable. But what needs to be done if this vision and imperative is to be implemented? In the next chapter I address these questions.

CHAPTER SIX

A SUSTAINABLE WORLD

Without a global revolution in the sphere of human consciousness, nothing will change for the better … and the catastrophe toward which this world is headed, whether it be ecological, social, demographic or a general breakdown of civilization, will be unavoidable.

Vaclav Havel[48]

6.1 Introduction

I hesitate to use the word sustainable because the definition of what sustainable means is not always clear. The complete absence of life on Earth might well be sustainable. It would certainly be sustainable without *homo sapiens.* After all, it has survived for the best part of 15 billion years without us. But what is intended is desirability along with sustainability.

In 1987 the United Nation's Brundtland Report, Ou*r Common Future*, defined sustainable development as "development that meets the needs of the present generations without compromising the ability of future generations to meet their needs". The report stressed the essential needs of the poor, to which overriding priority should be given, and the limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.

The definition is substantially anthropocentric, giving only limited emphasis to the imperative of nature conservation and environmental preservation. Also, it fails to give environmental guidelines where the interests of humans and nature are in conflict with one another (Hattingh, 2002:9). It is captive of the development and growth paradigm of rising productivity, accumulation and technical innovation. It ignores many of the real causes of poverty and environmental degradation, alluded to earlier, resulting from precisely the kind of development being practised; one that is materialistic and one-dimensional, highly concentrating, and exploiting both people and nature's resources. Sustainability in this context is nothing but rhetoric and illusion. What should be sought is development in the sense of the flourishing of human potentialities in their various dimensions, including the spiritual dimension of homo sapiens, ever tied to the global interactions of human beings with the Earth in its immense diversity and its dynamic equilibrium (Boff, 1997: 66-67). However, for humankind to flourish

122

and for the biosphere to be preserved will also entail substantially reducing and ultimately halting, even reversing our population growth rate.

6.2 The Population-Poverty-Population Trap

The world population is forecast to grow from 6.08 billion in 2000 to 8.92 billion in 2050. Population growth in the more developed, rich countries will be static, whilst the forty-nine poorest countries will see their total population grow from 668 million to 1.67 billion during the same period. This is where the main problem lies.

Fertility rates are falling worldwide, but not nearly fast enough in the poorest countries where aggressive programmes to further promote education, female empowerment, family planning, clean water and basic health care are called for. The crisis is both human and environmental. In these countries saving the environment will be largely dependent upon alleviating poverty through appropriate sustainable development programmes.

If capital grows faster than population a rising standard of living should ultimately reduce the population growth rate. In some parts of the world this is happening. But elsewhere neither economic growth nor its demographic response is taking place fast enough and in some countries the reverse is occurring. Economic welfare is falling and population growth rates are stagnant or rising. In such very poor countries capital growth often does not keep up with population growth because investable surpluses are siphoned off by foreign investors, to the luxury of local elites, to debt repayments, technical inefficiencies or mismanagement.
'The rich get richer and the poor get children.' The economic system of the world is blamed, supporting the call for structural change. Population growth slows individual capital growth by draining funds for schools, hospitals and basic consumption needs. Poverty perpetuates population growth by keeping people in a condition of no education, poor health care, a lack of family planning and no way forward, except to have a large family and hope children can bring in income or help with family labour. The result is, more poverty, more people, more poverty. The tragedy is both human and environmental. Increases in food production are only being won at great cost to the Earth, making future increases more difficult. This leads not only to more people but also to more deserts (Meadows, 1992: 37-40).

If world population stabilization is to be achieved family planning services must continue to be improved so that they are available to everyone. Political support on the local level has been shown to be the overriding factor in the success or otherwise of family planning programmes. Hand in hand with improved service delivery must go improved education and the empowerment of women. Unwanted pregnancies in poor countries are often due to a lack of availability, knowledge about, or acceptance of contraceptive devices. It is also frequently the case that women do not have control over their own fertility due to prevailing religious, cultural and community values. Male dominance and hence gender inequality is still widespread (Bouvier, 1999: 77-83).

There is reason to believe that the lack of income generating employment reduces women's power more directly than lack of education. It is all well and good to urge governments to invest in literacy programmes. But the results can be disappointing. Many factors militate against poor households taking advantage of subsidized education. If children are needed to work at home, sending them to school is costly. In patrilineal societies educated girls are perceived as less pliable and harder to marry off. In contrast, policies aimed at increasing women's productivity at home and improving their earnings in the market place directly empowers them. Greater earning power for women raises for men the implicit cost of procreation. Accordingly, whilst there is no denying the value of investment in education it is not necessarily a panacea for the population problem (Dasgupta, 1995: 415). The problem is a complex one for which there are no simple answers. All local factors must be taken into consideration when designing poverty relief programmes for a specific region.

Improving the economic security of the poor is essential to changing the options available to them so that they choose to limit their number of children. Providing cheap fuel and potable water reduces the usefulness of extra hands. When children are perceived of as expensive, we may finally have a hope of dislodging the rapacious hold of high fertility rates (Dasgupta, 1995: 418).

6.3 The Earth Charter

Universal human rights, economic justice and a culture of peace are of paramount importance. Fundamental changes in our values, our institutions, and our modern way of life (for those lucky enough to benefit from such a life) are called for if we are to achieve a globally sustainable

future for humankind in harmony with Nature. Once basic needs are met, human flourishing is primarily about being rather than having. We have the knowledge and technology to uplift the poor and to reduce, and where necessary reverse, the adverse impacts we have made on the environment. Our environmental, economic, political, social and spiritual challenges are interconnected and I have little doubt that by working together inclusive solutions to our problems will be found. New opportunities for harmonious prosperity for ourselves and for the great community of life, in which we hold a privileged position, will emerge. Every one of us shares a responsibility for the present and future well being of this community of life and should identify with it. As human beings we are citizens of a global community, of nations, and of local communities. They are all inextricably inter-linked. The spirit of solidarity and kinship with all life will be strengthened when we live with reverence for the mystery of being, gratitude for the gift of life and humility toward our place in Nature (Roberts, 2001). Expounded in this thesis is a shared moral 'world vision' of basic values founded on an ethics of compassion. It can provide the foundation for a new world community; one I believe that is already emerging.

The Earth Charter was drawn up as an outcome of the 1992 Earth Summit in Rio de Janeiro. Drafting of the Charter started in May 1995. It was finally released after a lengthy global consultation process organized in forty countries and was completed in November 1999. If only as a means of highlighting the challenges we face at this critical time of transition in our history, it is worth quoting its sixteen principles. The fact that such a document exists is a positive sign, even if it was a long time in the drafting. In the charter document itself there are a further fifty-six underlying sub-principles.

(i)   Respect Earth and life in all its diversity.
(ii)   Care for the community of life with understanding, compassion and love.
(iii)   Build democratic societies that are just, participatory, sustainable, and peaceful.
(iv)   Secure Earth's bounty and beauty for present and future generations.
(v)   Protect and restore the integrity of Earth's ecological systems, with special concern for biological diversity and the natural processes that sustain life.
(vi)   Prevent harm as the best method of environmental protection and, when knowledge is limited, apply a precautionary approach.
(vii)   Adopt patterns of production, consumption, and reproduction that safeguard Earth's regenerative capacities, human rights, and community well-being.

(viii)   Advance the study of ecological sustainability and promote the open exchange and wide application of the knowledge acquired.

(ix)   Eradicate poverty as an ethical, social, and environmental imperative.

(x)   Ensure that economic activities and institutions at all levels promote human development in an equitable and sustainable manner.

(xi)   Affirm gender equality and equity as prerequisites to sustainable development and ensure universal access to education, health care, and economic opportunity.

(xii)   Uphold the right of all, without discrimination, to a natural and social environment supportive of human dignity, bodily health, spiritual well-being, with special attention to the rights of indigenous peoples and minorities.

(xiii) Strengthen democratic institutions at all levels, and provide transparency and accountability in governance, inclusive participation in decision-making, and access to justice.

(xiv)   Integrate into formal education and life-long learning the knowledge, values, and skills needed for a sustainable way of life.

(xv)   Trust all living beings with respect and consideration.

(xvi)   Promote a culture of tolerance, non-violence and peace.[49]

Transforming our environmentally destructive world economy into one that can sustain progress and human flourishing requires a Copernican shift in our social, political and economic mindsets. It requires a recognition that the economy is part of the Earth's ecosystem and can sustain us only if it is restructured to be compatible and in harmony with it (Brown, 2001: 21). It requires a change of mind and heart, a sense of global interdependence and universal responsibility. It calls for imagination in developing and applying the vision of a sustainable way of life locally, nationally, regionally and globally. Our cultural diversity is a precious heritage. Difficult choices will have to be made, but we are ethically entailed to find ways to harmonize diversity with unity, the exercise of freedom with the common good, short-term objectives with long-term goals.

The common good is not exclusively human; it is the common good of nature. Because of the overlapping and inter-twinning of human beings with nature we must include the ecological dimension in the notions of world democracy and world economics. All beings in nature are citizens, have rights and deserve respect and reverence (Regan 1983: 143). We need a new world ecological order in kinship with the elements and with all animate and inanimate beings.

Without it we will be both materially poor and spiritually impoverished. Carl Jung understood the depth of such things:

> We all need food for the psyche; such food cannot be found in city dwellings, without a single patch of green or a tree in blossom; we need a relationship with nature … We need to project ourselves in the things around us; what is mine is not confined to my body; it extends to all the things I do and to all the things around me; without these things I will not be myself, I would not be a human being; everything around me is a part of me
>
> (Quoted in Boff, 1997: 133).

Jung may well have been a closet deep ecologist, but deep ecologist or not, in a world that has become increasingly complex, interdependent and fragile it behoves us all to join together to bring forth a sustainable global society in harmony with nature. By declaring our responsibility to one another and to the greater community of life we can create a global society that nurtures and rejoices in the love of life.

6.4 Guiding Principles for a Civil Society

Leading biologists, including Mae-Wan Ho, Elisabet Sahtouris, Janine Benyus, Dorion Sagan and Lynne Margulis, have identified certain life guiding principles (Korten, 2001: 328-329). As they accord with complexity theory, it is not surprisingly that they are also fundamental organizing principles of all healthy 'living' systems, including human economies and societies. They maintain that life is:

(i)   *Self-organizing and Cooperative.* Life's organizing mechanisms are highly decentralized and self regulating right down to the level of the individual cell – with each healthy living entity, each cell and organism, constantly adapting and balancing its own needs against those of the larger whole on which its own well being depends. Much of the decision making essential to maintaining our own bodily functions takes place at the cellular level through processes that suggest each cell has a sense of both its own identity and its function as a whole. The regulatory processes of biological communication are even more radically self-organizing, with no functional equivalent of the brain or central nervous system. Furthermore, the successful species within such communities are not necessarily the largest, strongest and most brutal competitors. Rather they are species

127

that find opportunities to meet their own needs in ways that contribute to the life of the whole, as with the honeybee that pollinates the flower in exchange for its nectar. Life is predominantly a cooperative enterprise, if it is to be successful.

(ii)   *Bounded by Managed, Permeable Borders.* To sustain itself, life must be open to exchange with its environment. Yet to maintain its internal coherence, it must manage these exchanges. Thus, life depends on permeable, managed boundaries. If the wall of a cell is breached, the cell dies. Multi-celled organisms need a skin or other protective outer layer to survive. The oceans, mountains and climatic zones that bound ecosystems serve to exclude invasive species. Even the biosphere of our planet depends on the Earth's gravitational field to hold in place an atmosphere and ozone layer that control the exchange of radiation with the larger universe to maintain the conditions necessary to planetary life.

(iii)   *Local and Adapted to Place.* Each living community adapts itself to the most intricate details of its particular physical locale, in turn modifying the physical landscape by creating and holding soil; capturing and holding water; and creating microclimates. Life thereby creates conditions suited to increasing its variety and the conversion of more of the inert matter of the Earth into living matter with the capacity for creative choice.

(iv)   *Abundant, Frugal and Sharing.* Biological communities are highly efficient in energy capture and recycling, for use and reuse within and between cells, organisms, and species. There is minimal loss, as the wastes of one become the resources of another. Frugality and sharing are the secrets of life's rich abundance, a product of its ability to capture, use, and store, and share available material and energy with extraordinary efficiency.

(v)   *Diverse and Creative.* Life does not exist either in monoculture or isolation from other life. Its rich diversity of species and cultures gives the biocommunity resilience in times of crisis and provides the building blocks for life's incredible capacity to adapt, learn, innovate, and freely share knowledge towards realizing new potentialities.

As David Korten says of these principles: "They point to the possibility of creating truly democratic, self organizing societies made up of strong, place-based communities with

permeable, managed borders each adapted to a diverse and vibrant local ecosystem abundant with life engaged in the creative, cooperative exchange of information, technology, and resources with its neighbours to assure every person an adequate and satisfactory means of living. There is nothing radical or exotic about such a concept. Think of it as a society based on a combination of participatory democracy, an affirming ethical culture, and market economies composed of responsibly managed, human scale locally owned enterprises" (Korten, 2001: 239).

If we are to transform the present uncaring, often uncivil capitalist model of society to a global society that is caring, we need to first understand the difference and then take the necessary steps to encourage the evolution of such a truly civil society. Figure 13 illustrates these differences as developed by Nicanor Perlas in his book *Shaping Globalization: Civil Society, Cultural Power and Threefolding* (2001).
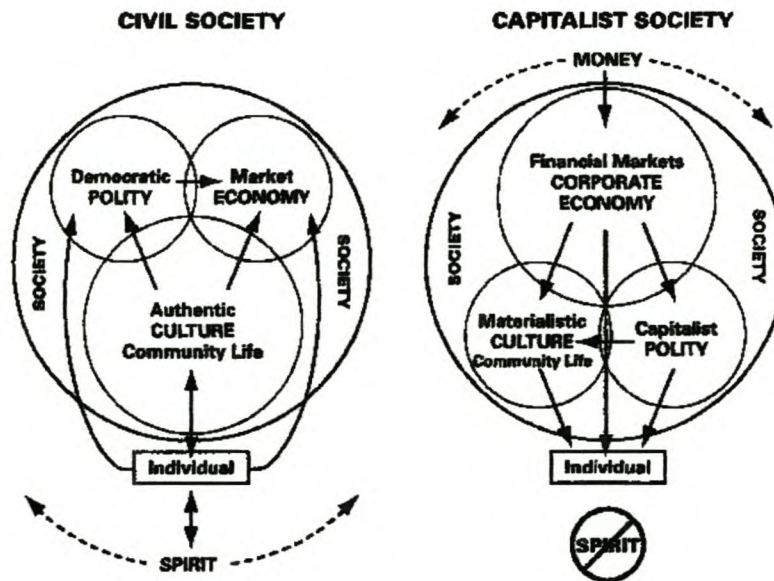

Figure 13.
Civil or Capitalist?

In the civil society, the cultural sphere is the dominant sphere of public life and is the product of the activity community life of free, culturally aware people whose personal identity is grounded in a deep sense of the spiritual unity of the whole of life. In such a society the market economy is a true market economy, not a manipulated one, and is comprised primarily of local enterprises that provide productive, satisfying livelihoods. Individuals share ownership in the productive assets on which their livelihood depends. This creates the possibility for the society to be radically self-organizing and predominantly cooperative. Individuals have maximum opportunity to develop and express their creative potential in service to the life of the whole. The powers and values that define civil society flow upward from the 'living spirit', as Perlas puts it, through people to culture and then to the institutions.

In a capitalist society, the economy dominates as the power and values flow downwards from money to economic institutions that in turn shape the institutions of government and culture to align society's rules, and values with financial interests. It leads to a materialistic culture and can lead to greed, competition and even violence dominating the inherent human capacity for sharing, cooperation and compassion. However, here in lies its vulnerability. Such a culture is contrary to most people's values and goodness (Korten, 2001: 330-31).

6.5 An Awakening

Perhaps the greatest threat to freedom and democracy in the world today comes from the formation of unholy alliances between government and business. This is not a new phenomenon. It used to be called fascism … The outward appearances of the democratic process are observed, but the powers of the state are diverted to the benefit of private interests.
George Soros [50]

In today's world there is a ground swell of opposition to corporate globalization supported by the institutions of global capitalism (such as the World Bank, International Monetary Fund and the World Trade Organization). This is because corporate globalization is increasingly perceived as leading to a suppression of true democracy and enrichment of the few at the expense of the poor. The world's largest corporations in alliance with the most powerful governments, and backed by the power of money, are intent on integrating the world's national economies into a single, borderless global economy without governmental interference. In the eyes of its

proponents it is the most efficient way, driven by technological innovation and economic growth, to spread democracy and create the wealth needed to end poverty and save the environment.

In opposition is an emergent alliance of civil society organizations. As Korten describes it: "This alliance is bringing together the most important social movements of our time in common cause, is self-organizing, depends largely on voluntary social energy, and is driven by a deep value commitment to democracy, community, equity, and the web of planetary life. It is a movement of a million leaders, each contributing ideas and initiatives toward shaping the whole" (2001: 5). Thus, it is the epitome of a complex adaptive system.

Its supporters, and I count myself as one of them, believe corporate globalization is indeed enriching the few at the expense of the many, replacing democracy with rule by corporations and financial elites, destroying the natural wealth of the Earth and its biodiversity, destroying the rich diversity of our human culture and breaking down relations of trust, caring and compassion that are the essential foundation stones for a truly civil society. Can it be right that the wealth of the world's 84 richest people is greater than the GDP of China, with 1,3 billion people? Is it acceptable that the 200 largest corporations control 28% of world economic activity while employing less than 0.25% of the world's economically active people? I think not. Both capitalism and communism acknowledge the truth of the aphorism 'money is power'. Thankfully in most parts of the world communism is dying unmourned, but its old enemy, capitalism, is apparently taking over its assault on life, equity and democracy. The tenets of both ideologies are not all bad, but when basic principles are perverted by human greed and a lack of compassion, the result is exploitation, poverty and environmental desecration.

At the present time with the power and wealth residing with the proponents of capitalism (and this power extends to media control and control over governments and police forces), the odds are stacked against the 'opposing alliance'. But the exercise of raw power against an aware public almost always proves self-defeating. The demise of the Soviet Union, the fall of the Berlin Wall, and the ending of apartheid here in South Africa are recent examples. Winning wars often rests on winning the hearts and minds of people. The Vietnam War was a classical example.

In the United States itself, the world's wealthiest and most powerful country, there is a deep awakening of what may be called cultural consciousness. In their book, *The Cultural Creatives: How 50 Million People are Changing the World* (2000), Paul Ray and Sherry Anderson[51] reveal

a changing balance in the distribution of adult Americans amongst three cultural groupings that they identify:

(i)   *The Modernists.* At 48%, the largest group who accept the commercialized, urban-industrial world as the obvious right way to live, honouring the drive to acquiring money and property.

(ii)   *The Traditionals.* About 25% and declining. Down from about 50% after World War II. They believe in traditional values (community, family and caring for others) and gender roles. They tend towards religious conservatism and seek stability in relationships.

(iii)   *The Cultural Creatives.* 26% and rising, up from less than 5% in the early 1960's. 60% are women. They share the Modernists' receptiveness to change but reject materialistic hedonism, the cynicism of the corporate media and the greed and individualism if the consumer/corporate culture. They share with the Traditional a concern for human relationships and contributing to society, but reject Traditionals' tendencies towards survivorism, sexism, exclusion, and belief in the right of humans to dominate Nature.

It is the *Cultural Creatives* that provide the leadership for the movements and initiatives opposed to the capitalist global masters. The cultural shift in the United States gives hope for us all. It is mirrored in Europe and is part of a global trend. There is a growing trust in the personal inner sense of what is right. This trend is accompanied by a declining interest in economic gain and a growing desire for meaningful work and a sense of purpose in life (Korten, 2001: 321). In other words, in being rather than having. Until recently, in the developed world in particular, many such people may have felt culturally violated, politically dispossessed, and out of step with the main stream as they were ignored by the media and were underrepresented by traditional political parties. But this is changing, and with surprising speed. Independent parties, such as the Green Party, are growing in many countries, including the United States. At the last presidential election in 2000 Ralph Nader, Green Party, had the greatest support for any American third party candidate ever.[52]

The voice of the so-called Cultural Creatives is being increasingly heard through the publications and programmes of the independent media, the Internet, and through protest. And street protest is no longer just a strategy adopted by extremists. Witness the demonstrations in

Seattle in November 1999 against the World Trade Organization and analyze who it was taking part. Witness, in March 2003, the unprecedented mass marches against the war in Iraq held in London (estimated at 1.5 million people) and elsewhere and see who was taking part. Ordinary people from all walks of life who doubted that the war was really about weapons of mass destruction, but about 'regime change' and oil – as has become abundantly clear it was.

Experience teaches us that the underlying forces of powerful social change build up silently and invisibly over decades until at some dramatic moment in time the seemingly impossible occurs. Who in 1988 would have predicted what transpired in just a few years in the Soviet Union, Eastern Europe and South Africa, all of which was inter-linked? Until recently, the silent rejection by many people of capitalism's excesses was invisible. But, following Seattle it is now coming out into the open more and more. As the diverse groups opposing the status quo link up, and the alliance grows, 'a crystallization of connected webs' will suddenly occur 'at a phase transition' as it did in Eastern Europe in 1989. This is the same phenomena that was illustrated so insightfully by Kauffman in his random graph experiments with buttons and threads in his search for a theory of life's origins (3.3). Such a web is almost certainly autocatylitic, self-organizing self sustaining and alive, and applies equally to human behaviour as it does to buttons and threads.

The message is, if one believes in the cause, to heed the call of Anita Roddick: " Take it Personally"[53] and join many fellow traveller's on an exciting new path into the future. Support those groups already out there, or form your own local group, pushing for change. Large events often have small beginnings; the famous 'butterfly effect'.

The challenges we face are immense, as we take the first steps in making the required transition to a more sustainable, caring, compassionate and meaningful way of life. One in which our inter-linked moral, spiritual and material aspirations may coevolve as we recreate ourselves as people, communities and societies in harmony and as part of the biota and Gaia. Whether this is achieved through self-organization or autopoiesis, is academic, for in being pragmatic it will not make much difference. It is all very complex, daunting yet exciting. The future is uncertain but we have a responsibility to do the best we can for the benefit of all living things, present and future. We will make mistakes, but we will learn as we go along provided we keep an open mind, and encourage and capitalize on the inherent goodness that exists in every one of us.

We are called upon to engage in a transition for which there is no blueprint. But with an understanding of the complexity of the problems and challenges we face, and an understanding of how complex adaptive systems work, we can succeed. Complexity can be harnessed and made to work for us. To guide us, it should be possible to generate a set of future scenarios, in the form of crude, integrative policy studies, based on evolutionary and non-linear simulations, and cooperative strategies. Such studies are already underway. For example, Project 2050, led by the World Resources Institute, the Brookings Institute and the Santa Fe Institute, with the participation of people and institutions worldwide. An early Project 2050 document put it this way: "We are all in a situation that resembles driving a fast vehicle at night over unknown terrain that is rough, full of gullies, with precipices not far off. Some kind of headlight, even a feeble and flickering one, may help to avoid some of the worst disasters" (Gell-Mann, 1994: 366).

The Earth, and indeed the Universe, is participatory; it is a most intricate web of connections and relationships, enveloping everything, including *homo sapiens*. If we are to live up to our name in a complex world then, as regards the Earth, the overriding challenge we face is to facilitate a transition to a future world that functions more effectively than it does now as a composite, richly diverse complex adaptive system.

Notes

1. "*Unified Theory*", San Jose News, 23 January 2000.

2. Unless otherwise indicated all word definitions are taken from Pearsall, J. 1999 (Ed.). *Concise Oxford English Dictionary, 10th Edition.* Oxford University Press, Oxford.

3. Mark Twain, (1835-1910) US writer and humourist. *What is Man?* (1903).

4. Henry Miller, (1891- 1980). US writer. *Tropic of Capricorn* (1939), said this, but for 'Confusion', not 'Complexity'.

5. Edward Lorenz, (1917-). US meteorologist. Quotation first used by mathematician James Yorke in regard to chaos theory in 1972.

6. Quoted in Cilliers (1998), p. 96.

7. From talk given by John Holland at the Santa Fe Institute (date unknown).

8. Quoted in Cilliers (1998), p.100.

9. Fitness landscapes. Modern biologists use the image of an adaptive fitness landscape whose peaks represent high fit forms, and see evolution as the struggle of species (or agents or companies) to climb towards those peaks driven by mutation, recombination and selection.

10. Science Magazine 1972. *More is Different.* Referred to in Waldrop (1993), p.81-82.

11. The term rational thought is used in the strong sense of following rules or an algorithm to arrive at a result by a process of logical reference.

12. Stated by Francisco Ayala at a meeting on Evolutionary Progress at Chicago's Museum (date unknown). Cited in Lewin (1999), p.168.

13. A-Life conference, Santa Fe (date unknown). Cited in Johnson (1996), p.256.

14. Cited by Dowd, M. 1990. *Earth Spirit: a Handbook for Nurturing an Ecological Christianity.* Twenty-Third Publications. Mystic, Conn. Also cited in Boff (1997) p.200.

15. From . White, F. 1987. *The Overview Effect.* p.39. Houghton Mifflin Company, Boston. Cited in Boff (1997) p.200.

16. From White, F. 1987. *The Overview Effect.* p.123. Houghton Mifflin Company, Boston. Cited in Boff (1997) p.200.

17. See also Melvin Calvin, 1969. *Chemical Evolution.* Referred to in Johnson (1996). p. 227.

18. The Red Queen Effect. A phrase coined by Lee Van Valen, paleontologist, University of Chicago. *From Alice in Wonderland,* based on the comment by the Red Queen to Alice: *"(I)t takes all the running you can do, to keep in the same place".*

19. In the Prisoner's Dilemma there are two prisoners, arrested for a crime they both committed, are separated and offered a choice by the police: inform on your partner and receive a reduced sentence, or remain silent. If both remain silent, both go free, but if one prisoner informs, the other receives the maximum sentence. If both inform they both go to prison, but with lighter sentences. Thus each has two choices: cooperate (remain silent) or defect (inform). Each must make the choice without knowing what the other will do. No matter what the other does, defection yields a higher pay off than cooperation. The dilemma is that if both defect, both do worse than if both cooperated.

20. In game theory, an outcome or set of strategies, one for each player, is in Nash equilibrium if it yields an outcome such that no player can improve his or her position by unilaterally withdrawing from it. This is the 'both defect' position in the Prisoner's Dilemma.

21. For more on punctuated equilibrium theory, see Gould (2002), p.37.

22. Goerner S. J., 1994. Chaos and the Evolving Ecological Universe, *World Futures General Evolution Studies,* Vol.7. Cited in Dimitrov and Fell (2003).

23. Baden J., Foundation for Research on Economics and the Environment. *Wall Street Journal*, 19 August 1991. Cited in Lewin (1999), p. 204.

24. See for example, Drucker, P. 1995. *Managing in a Time of Great Change*. Truman Talley Books, New York.

25. Reason, from Shaw's *'Maxims for Revolutionists'* in his play *Man and Superman*.

26, Blackburn, S. 1994. *Oxford Dictionary of Philosophy*. Oxford University Press, Oxford.

27. The Golden Rule: " Do unto others as you would others do unto you" comes from the Bible, Matthew 7, verse xii. Shaw was clearly an early postmodernist. He said, " Do not do unto others as you would they should do unto you. Their tastes may not be the same". Same source as note 25.

28. From Joseph Heller's novel of the same name:

> There was only one catch and that was Catch-22, which specified that concern for one's own safety in the face of dangers that were real and immediate was the process of a rational mind. Orr was crazy and could be grounded. All he had to do was ask; and as soon as he did, he would no longer be crazy and would have to fly more missions. Orr would be crazy to fly more missions and sane if he didn't, but if he was sane he had to fly them. If he flew them he was crazy and didn't have to; but if he didn't want to he was sane and had to.

29. See note 25.

30. For appraisals of *After Virtue* (1981), see Bernstein (1994) and Fuller (1998*). After Virtue* was reissued in 1985 (corrected, with postscript). Tenth Impression 2000.

31. *Telos.* Greek: end, or purpose.

32. *Phronesis.* Greek: intelligence, prudence. Practical wisdom, knowledge of the proper ends in life. See 4.5.8.

33. F.H. Bradley, 1876. *Ethical Studies. Essay V: My Station And its Duties,* paragraph 16. Cited in Norman (1998) p.117-8.

34. See credits on backcover of McIntyre's *Dependent Rational Animals,* (1999*).

35. Dalai Lama XIV. 1999. *The Dalai Lama's Book of Wisdom*. p. 91.

36. Daintith, J. et al. (eds.) 1993. *Bloomsbury Thesaurus.* Market House Books, Aylesbury, UK.

37. Jeremy Bentham, 1789, wrote in *An Introduction to the Principles of Morals and Legislation,* chapter 17:

> The day may come when the rest of the animal creation may acquire those rights which never could have been withhelden from them but by the hand of tyranny. The French have already discovered that the blackness of the skin is no reason why a human being should be abandoned without redress to the caprice of a tormentor. It may one day come to be recognized that the number of legs, the villosity of the skin or the termination of the os sacrum are equally insufficient for abandoning a sensitive being to the same fate. What else is it that should trace the insuperable line? Is it the faculty of reason, or perhaps the faculty of discourse? But a full-grown horse or dog is beyond comparison a more rational animal than an infant of a day or a week or even a month old. But suppose they were otherwise, what would that avail? The question is not, Can they reason? Nor can they talk? But, Can they suffer?

38. David Hume, 1739. *A Treatise of Human Nature.*

39. Schopenhauer did not discuss the fourth ultimate motive, "desire for one's own woe'.

40. From Schopenhauer's *The World as Will And Representation*, i. 282.

41. See *The Book Of Mencius* 2A: 5, in Wing-tsit Chan, *A Source Book in Chinese Philosophy*, Princeton University Press, Princeton. 1963, p.65.

42. Works by Thich Nhat Hanh include *The Sun in my Heart*, 1988, *For a Future to be Possible,* and *Love in Action,* 1993. All Parallax Press, Berkeley. Cited in Hayden, T. 1996. *The Lost Gospel of the Earth*, p. 167-9.

43. J. Baird Callicott, 1989. *In Defense of the Land Ethic,* p.52-54.

44. Vaclav Smil, 1993. *Global Ecology.* p.35.

45. World Scientists' Warning to Humanity. Issued in Washington D.C., 18 November 1992. Cited in the Preface to VanDeVeer (2003), p. xxvii-xxx.

46. Lao Zi, *Dao De Qing.* Lao Zi was a recluse who became a historian in the secret archives of the Chinese Zhou dynasty over 2000 years ago. Quoted in Smil, V. 1993, p.206.

47. Ramon Gomez de la Serna, (1888-1963). Spanish novelist. *Ismos* (1931).

48. Vaclav Havel, former president of the Czech Republic. Date unknown. Cited In Korten (2001), p.337.

49. See www.earthcharterusa.org.

50. George Soros, International financier, *Open Society: Reforming Capitalism*, 2000. Public Affairs, New York. Cited in Korten, (2001), p1.

51. As well as Ray and Anderson's book see also an interview in *Yes! A Journal of Positive Futures*, Winter 2001 pp.15-20.

52. Nader won 7% of the vote. He would probably have done better still had it not been for an agreement with Al Gore that they would not compete against each other in States where doing so could have split the vote and hand the State vote to George Bush. Some analysts think that even by running for President, Nader cost Gore the election.

53. Taken from the title of Anita Roddick's book *Take it Personally* (2001).

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