Cohesion

The Making of Society

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Dedication

This book is dedicated to Mum and Dad.

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Preface

"It took just over a year after the first shots at Lexington for rebellion to turn into outright revolution. On 4 July 1776, in the austere chamber normally used by the Pennsylvania assembly, the Declaration of Independence was adopted by representatives of the thirteen secessionist colonies at the Second Continental Congress. Only two years before, its principal author, the 33-year-old Thomas Jefferson, had still addressed George III in the name of 'your subjects in British America'. Now the transatlantic or 'continental' Britons had become American 'Patriots'. In fact, most of the Declaration is a rather

tedious and overstated list of wrongs supposedly inflicted on the colonists by the King, whom they accused of trying to erect a 'Tyranny over these States'. It bears all the hallmarks of a document heavily revised by an outsize committee. It is Jefferson's preamble that people remember today: 'We hold these truths to be self-evident, that all men are created equal, that they are endowed by their Creator with certain inalienable rights, that among these are life, liberty and the pursuit of happiness.'"

(Ferguson, *Empire*, p.92)

This quote is of interest as it contains a snapshot in time of the formation of a new society. The birth of a new cohesive social entity, that we now call the United States of America. The birth of new societies has often been a violent, primeval process; almost like the emergence of new land itself from hot volcanic rifts. As is traditional in human affairs, the US Declaration of Independence was a little bloody, and occupied some tumultuous years; yet somehow from such pivotal moments in time, entirely new forms of unified cultural expression can emerge and form the foundation of whole new states and empires. However, as Ferguson rightly points out in his text, the real battle was between the Patriots and the local Loyalists, rather than with the remote British Crown itself. The battle was between two opposing world-views in the minds of the colonists themselves, each striving to hold a collective vision of the principles by which their society should function. What is of interest is how any such revolution results in a new cohesive whole. Ferguson articulates this succinctly:

"Perhaps the most remarkable thing about the Declaration of Independence was that the representatives of all thirteen colonies were able to sign it. Just over twenty years before, the divisions between them had seemed so wide that Charles Townshend had found it 'impossible to imagine that so many different representatives of so many different provinces, divided in interest and alienated by jealousy and inveterate prejudice, should ever be able to resolve upon a plan of mutual security and reciprocal expense."

Which sounds rather more like present-day US politics! It is quite ironic that the roles are now reversed, and it is the British Parliament that jumps when the White House calls. (Apparently, subservience has been redefined as a 'Special Relationship'.) So it is time to ask what is the theme of this book? The birth of the US is used as a prime example of a new society emerging out of diverse and disparate cultural groups. This book attempts to address some of the interesting questions that revolve around the formation and dissolution of human societies in general. Specifically whether, and how, we can shape the nature of cohesion present in modern societies. Some example questions we will review include: Why are complex systems able to form stable structures at all? Why are there companies, states and societies in such diverse forms? In particular we will attempt to understand what makes any culture, or organisation stable, and whether it is possible to increase the degree of social cohesion? The first two chapters lay the groundwork by introducing some key topics from the fields of Complex Systems, Networks, and computer-based modelling of social systems.

This book aims to address these questions and provide some ideas on how we may understand the principles that guide the development, stability and growth of complex social systems. The question which will be returned to is: *what forces create and sustain an integrated whole*? In other words, what exactly is 'cohesion', and why should we be concerned with its scientific investigation. The why is actually the easiest part. When economies, states and societies lose their cohesion, people suffer; to be precise a lot of people end up paying the cost. In the recession of 2008/09, as I write this text, one of the images that has resurfaced in the common media, is an iconic image from the 1930's Great Depression that depicts the suffering of a poor migrant mother and her children. Florence Owens Thompson, (born Florence Leona Christie), was the subject of Dorothea Lange's famous photo, *Migrant Mother* (1936). For me this image struck a deep chord and acted as an impetuous to complete this book. The tragic example of Mrs Thompson and her poignant image, might fairly stand as the epitome of all those who have suffered down the annals of history, in famines, wars, and economic busts. It is the tale of human endurance and perseverance in the face of overwhelming hardship and trials.

In chapters 3 and 5, we will attempt to address the vexing, (and topical,) question of why do economies collapse in such perpetual boom-bust cycles? However, the rest of the book is broader than just economics. We are looking

for deeper clues as to what makes society work, i.e. what processes foster cooperation, altruism and harmony in society. Some of the specific themes that will be addressed revolve around the impact of trust, consultation and cooperation, in the building of cohesive communities and organizations. In particular, the power of trustworthiness, spiritual and moral values and cooperation, will be explored in detail. With specific examples from history, networks, commerce, warfare and computing used to illustrate their pervasive impact on social cohesion. The remainder of the chapters hangs together in a vaguely ordered, but not necessarily linear manner. (Linear thought, I strongly feel may be a requisite for accountants and actuaries, but becomes a strait-jacket when applied in the physical and social sciences.)

The text has also been heavily influenced by the work of Francis Fukuyama, although not by his infamous work, '*The End of History and the Last Man'*, but by his lesser known piece on '*Trust – The Social Virtues and the Creation of Prosperity*'. This is a truly excellent book that deserves wider study. We will consider this work in more detail later, but in summary it highlights through a careful comparison of nation states economic development, the impact and pivotal role played by trust and social capital.

Who should read this book? Well firstly I would like to reach the curious general reader who has browsed through many pop-science texts and found them either baffling, or even more verbose than this volume. Second, I would really like to reach graduates of the social sciences, in order to convey some excitement and interest in applying Complex Systems theory to comprehending current social phenomena. Finally, if the text is of some small value to readers familiar with the fields of interest, that would be a bonus.

A few comments on the author are probably advisable at this point. I have a checkered scientific education and this will be reflected in the fluid expositions that will flow from chapter to chapter, like some meandering stream. (I also have a poetic bent, although having failed my high school English Literature exam, not a very gifted one.) So where am I coming from, well I have a deep and long-standing interest in the fields of Chaos and Complexity theory. Yes it is sad, but it keeps me off the streets, so a win-win situation for everyone else! Academically I started out in Physics, wandered through Electronics and finished with a PhD in Autonomous Robots; (the R2D2 kind not the car assembly kind). That was a fun time, designing and

building bizarre mobile contraptions, with more silicon than an Intel Fab plant and more sensors than the Hubble telescope. I was then recruited by a major European telecommunications company (BT), and asked to research anything that would ideally lead to some profit. I have since spent several years researching AI, and Complex Systems, and their application to e-commerce and network security.

So I have far too many certificates and not enough social skills! Anyway, back to this book, my aim was to address a few key questions, currently being asked in many fields: from biology and economics to computer science and robotics. The crux of which is under what conditions do human social systems achieve stable and robust states.

This may appear to be overly ambitious, but such questions are of profound importance to the wider human race at the current time. We are in the midst of greater social, economic and technical change than at any time in history. Understanding how our current political, commercial and social systems operate, and whether they will retain any stability is rather important. To be honest, all is not well with the functioning of our modern globalized society, and its cohesion and stability are under serious threat from numerous factors; whether social, economic, demographic or climate change related. There are harsh consequences when we collectively fail to communicate. The current economic malaise, of 2009, is but a prelude to far worse, if we fail to learn the lessons of note.

Returning briefly to the early days of the United States, the character that most resonates with the theme of this book must be Benjamin Franklin. Franklin's life is well known as a printer, satirist, author, politician, scientist, inventor and diplomat. In relation to this work, his life is an exemplar of a social super-hub who bridged cultures, continents and class. Franklin was social cohesion in action. Via his founding scientific work on the nature of electricity he also helped lay the foundations for modern communications and technology; the themes for chapter four. In summary, Franklin was pivotal in forging the Union of the post-colonial states and in acting as a social bridge to the old world in England, and then as the US Ambassador to France. He was also one of the boldest anti-slavery advocates of his era. In contrast to many of the leading lights of the US independence movement, who merely paid lip service to the emancipation of the blacks. His contemporaries, however,

clearly recognized the magnetizing influence such a figure could play in times of great change:

"*He seized the lightning from Heaven and the scepter from the Tyrants*." (Turgot)

In Franklin's life we witness an example of how at the right moment, it is the smallest of events, or actions of a single individual, that can catalyze the foundation of empires. Most of all his life embodied how the cohesion of great states is forged from the beliefs and values of a few souls. Those who value vision, action and belief in equal measure. In chapter six we address the influence that vision and beliefs still play on social cohesion. In chapter three we examine the vast subject of the rise and fall of civilizations, (somewhat briefly), and consider the forces that built and destroyed them. Beginning with: ancient Egypt, Rome, China, and the British Empire; before finally returning to the current unipolar world of the USA. Hence, the references to the birth of the United States act as a starting point for the voyage ahead.

Another major theme running through the text is how the power to communicate has shaped human society and provided the means to bind humanity together. From smoke signals, and the electric telegraph, through to fibre optics, and the Internet. As we stride into this new millennium the manifest boom in all forms of communication is bringing immense capabilities to form new social collectives and positive cultural developments. It is also shaking the historical edifices of party politics, tribal identities, race and the whole panoply of human society. We will explore the relative positive and negative impact of communications, and broader technology in general, on the cohesion of society. This book does not contain many answers, but posing the questions in a coherent and collected manner may still prove to be of some value. There will also be some nice quotes by famous people, and a few jokes to lighten the mood.

"*In the beginning there was nothing, and it exploded*."

Terry Pratchett, (on the big bang theory)

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Chapter 1

Cohesion: Patterns and Complexity

"The process of evolution may be described as differentiation of structure and integration of function. The more differentiated and specialized the parts, the more elaborate co-ordination is needed to create a well-balanced whole. The ultimate criterion of the value of a functional whole is the degree of its internal harmony or integratedness, whether the "functional whole" is a biological species or a civilization or an individual. A whole is defined by the pattern of relations between its parts, not by the sum of its parts; and a civilization is not defined by the sum of its science, technology, art and social organization, but by the total pattern which they form, and the degree of harmonious integration in that pattern."

(Koestler, 1989)

1. Introduction

The Cosmos is a symphony played with recurring leitmotifs at all scales. Fractal clouds of water vapour crown our ocean world, while families of galaxies cluster together in bizarre fractal geometries. Crescendos of supernovae and bass-note black holes reverberate across space-time, like the bass drums and horns in Berlioz's Symphonie Fantastique. Pulsars mimic cosmic metronomes keeping perfect time for the forging of stars across vast nebulae. We behold a cornucopia of living and socially complex structures

across the earth, with infinite forms and patterns. Why? Of course evolution informs us of how organic complexity emerges from simpler forms. But why does any group of social agents, cohere into distinct groups? Surely the energy cost is immense in the face of the relentless second law of thermodynamics.

The field of Complex Systems, or Complexity Theory, has recently appeared precisely in order to develop a set of coherent theories for the formation and behaviour of all complex and self-organizing systems; (often abbreviated to CAS - Complex Adaptive Systems). However, as with all young branches of science its promoters are often over-exuberant, proclaiming it as an all-conquering paradigm shift. More cautious and experienced commentators have praised the high ambition of realizing new universal laws describing the *élan vital* of all life and complex structures, but advise caution in such grand ventures. Edward Wilson in his major work, *Consilience* (Wilson, 1998), provides just such a critique of the field of Complexity Theory; advocating a firmer basis in theory, and existing bodies of scientific knowledge.

However, it remains the case that a crucial requirement of modern science is the fusion of multiple disciplines into deeper and stronger interdisciplinary research threads. In this regard the institutes and research centres engaged in complex and nonlinear systems research represent the core of such work. Unfortunately, it also remains an almost hopeless case to acquire the research funding required for any fundamental interdisciplinary activity.

This text approaches the issue of complexity by focusing on one specific and crucial aspect of such systems, i.e. how do complex structures bind together? Specifically, what processes enable human social systems to form stable groups, whether the group is your local cricket club, a political party, tribe, city or nation state? The opening quote by Arthur Koestler is used precisely in order to frame the key question, which is laced throughout this text, i.e. what forces create and sustain an integrated whole? As stated in the preface, what exactly is cohesion and why should we be concerned with its scientific study?

By addressing this question we may assist in the complex social and technological challenges we face in the present century. It will be argued that distinct signs of global cohesive social and technological structures are in fact

now self-assembling from the mismatched economic and political systems currently employed. If we can understand how and why such collectives emerge, then we may be able to steer the formation of healthier, stable and coherent societies. Failure to direct such emergent forces may lead to potentially bleak technological or sociological future scenarios. There are many potential paths facing humanity at this juncture in history, but selecting those that offer an aesthetically or morally sound option will be a greater challenge than that faced by any of our ancestors. (A topical example is the recent debate in British politics on whether to allow human-animal hybrid embryos. The science behind this communicates one message based on a simplistic cost vs. risk analysis, but the moral dimension has not been sufficiently addressed. Specifically, in the absence of any coherent religious motion on the debate, there is a serious imbalance towards the purely technical dimension.)

The focus of the text is on the physical forces acting on complex systems, which also includes the dimension of sociological and technological pressures. To be honest, there is a sub-agenda that reflects the authors optimistic perspective, i.e. that humanity can truly develop more integrated and cohesive societies. There are many related and critical questions which science is also beginning to consider. Firstly, how do complex systems form and grow, whether in morphogenesis within living organisms, or within company formation on the Nasdaq? A second related question is why do stable collectives of biological cells, or social units, break apart once formed? As in the ancient Chinese yin-yang symbology, creation appears to be intertwined with destructive forces. This theme will also be explored. Finally, are there any guiding heuristics we can utilize to assist in the creation and design of useful groups and structures? This text is therefore not solely about complex systems, although they form a connecting thread within many of the topics we will cover. The following introduces some of the themes we need to address. (One point to note is that the book often uses quotes from Wikipedia where basic historical references are required, and these are clearly cited. The Wikipedia experiment is one of the best examples of the power of collective information sharing, and reflects the open philosophy guiding the author in the formation of this text.)

1.1 Complexity Unbound

"The Greatest Challenge today, not just in cell biology and ecology but in all of science, is the accurate and complete description of complex systems". (Wilson, 1998, p.93)

This book addresses several subject areas that encompass various elements of the processes we are attempting to understand. This chapter provides a preliminary overview of the forces and patterns of interest; however let's start with a basic definition of complex adaptive systems.

"*A Complex Adaptive System (CAS) is a dynamic network of many agents (which may represent cells, species, individuals, firms, nations) acting in parallel, constantly acting and reacting to what the other agents are doing. The control of a CAS tends to be highly dispersed and decentralized. If there is to be any coherent behavior in the system, it has to arise from competition and cooperation among the agents themselves. The overall behavior of the system is the result of a huge number of decisions made every moment by many individual agents."*
(Waldrop, 1994)

This definition is useful as it incorporates some core aspects of complex systems that are pivotal in understanding their wider societal impact. Firstly, they are in a state of constant change, never static; in a state of flux would be a suitable description. This quality echoes the words of the Greek philosopher, Heraclitus, whose famous expression aptly captures the nature of complex systems: "*You could not step twice into the same river; for other waters are ever flowing on to you."*

Secondly, the agents that compose such systems are constantly interacting in dynamic and unpredictable ways. Finally, the emergence of any large-scale coherent patterns or social structures is a result of the many interactions between the agents themselves, rather than something imposed by an exogenous grand designer. (The pervading philosophy in the CAS view of the world is a bottom-up approach, rather than a top-down model.) We will see in the following chapters how these properties shape coherent behaviour and phenomena across the spectrum of human society.

1.2 Principles and Forces

In order to address these questions we require some understanding of the underlying forces and common elements within complex systems. The issue is compounded by the need to describe sets of interlinked qualities, as opposed to traditional singular measures such as the entropy (i.e. the degree of order within a system) or the energy state of a system. There is within the scientific community an urgent technical goal to create metrics in order to adequately express the macro states within broad classes of complex system. (Recent work has considered the creation of new measures of entropy, such as Tsallis Entropy, but this is rather beyond the level of this text.) The following non-exhaustive list addresses some of the key features and mechanisms of interest within complex systems.

1.2.1 Patterns

An age-old puzzle is what defines a pattern? We would consider a rock as being a cohesive unit, but not in the sense that we are attempting to define here, i.e. a complex arrangement of matter that requires energy to sustain itself. (We will also query whether this is a sufficient definition). So what constitutes a pattern? Turning to the good old-fashioned paper dictionary, we find:

design: a repeated decorative design, for example on fabric

a zigzag pattern

regular form: a regular or repetitive form, order, or arrangement

a predictable pattern of behaviour

prototype: an original design or model from which exact copies can be made

This is not really useful as we are getting recursive logic, where patterns are defined by examples of other patterns! Let's consider a simplistic example. What is the difference between a rock and a whirlpool? Both are complex structures composed of vast numbers of atoms. However, a significant number of physicists and complex systems scientists study whirlpools, while few contemplate rocks, (except those with Zen leanings; of course Japanese Zen

gardens may contain whirls of pebbles, but I digress). A whirlpool is of interest as a CAS, since it is a 'spatio-temporal' structure. It exists as a result of the interplay between its constituent matter and the energy flow which drives it. Remove the energy and the structure dissolves. Such is the way of life and all of the complex systems we are interested in for the purpose of this text. (A nice reference on the topic of patterns and complex systems is: *The Self-Made Tapestry, Pattern formation in nature* by Philip Ball (1999).)

The requirement for a constant flow of energy then is perhaps the best defining condition for any CAS that may be of interest. During the following chapters we will need to carefully elaborate and expand our definitions and worldview of complexity. For example, one of the central problems when reviewing the social domain is simply the ability to measure the degree of cohesion across a social group. What should be the defining parameters for measuring cohesion? For example, in the case of a company we could measure the turnover of staff as an indicator of morale, and hence group cohesion. However, as the scale and complexity of social structures increase, it becomes increasingly difficult to formalize. A city is clearly a persistent spatio-temporal system, which if viewed over a sufficient length of time, has the distinct appearance of a cohesive, pulsating, living entity. Yet its composition of citizens, shops, and businesses is constantly changing, day to day and year to year. One variable that does have more permanence is the transport networks that sustain and feed a metropolis. These evolve over time as well, but often new networks trace over the paths of earlier roads and byways. This aspect is why we need to spend some time in chapter two on the central role played by all forms of networks in sustaining cohesive patterns. In chapter four we look in more depth at the cohesive role played by transport networks.

Next is the critical question, if a social system is cohesive, over what time frame will it remain so? For example, North Korea has been stable for fifty years. Will it remain so? Probably not, based on the evolutionary path followed by most communist regimes. Such extreme regimes have proved to be stagnant and in stasis, rather than stable in a dynamic sense of the word. Fortunately, the physical laws of the universe seem to abhor stasis even more than a vacuum. The living and dynamic polity that surrounds such regimes swirls incessantly, and places an irresistible pressure to change and evolve on any social structure that holds itself rigid. We will return to the political domain in chapter three.

1.2.2 Harmony

The human mind clearly has preferences for ordered patterns and we seek such within our art, music, literature and indeed within scientific theories, where parsimony and order are highly prized elements of any substantial theory. (A great text in this regard is *It Must be Beautiful* (Farmelo, Ed., 2003), which contains a series of wonderful expositions by leading figures from each of the major scientific disciplines.) But what constitutes a harmonious pattern or arrangement?

"*The term harmony originates in the Greek (harmonía), meaning "joint, agreement, concord". In Ancient Greek music, the term was used to define the combination of contrasted elements: a higher and lower note.*" (Wikipedia, 2009)

Frequently, as seen from the earlier definitions, we find that concepts such as harmony, or pattern, slip into recursion. Even more problematic is that our mental perception of groups or wholes is quite subjective; (the topic of Gestalt psychology is an interesting starting point for studies of pattern perception (Kohler, 1992).) We assign meaning to what we perceive to be spatially or temporally correlated, and our neural network brains are well evolved to this task. Part of why this is a difficult subject is reflected in the difficulty current digital computers have in reproducing human skills, for example face recognition or the visual processing of a scene. There is something quite subtle, analogue and complex in separating correlated signals from rich data environments, i.e. the real world.

So is harmony just a balancing of correlated elements? Or does it entrain something more fundamental? It is unlikely that we will soon realize an answer to this question, but in addressing the issue some insights may be gained into what defines a group or cohesive system. The text by Denis Noble is an excellent example of a scientific description of biological systems that uses harmony and musical metaphors to capture the dynamic and cohesive nature of all living systems (Noble, 2008.) Harmony is not just a delicate balance of elements therefore, but rather a subtle and constantly dynamic interplay between the threads within a greater whole. The following quote from one of Darwin's notebooks is a nice usage of the term in this context:

"What a magnificent view one can take of the world Astronomical & unknown causes, modified by unknown ones. Cause changes in geography & changes of climate superadded to change of climate from physical causes—these superinduce changes of form in the organic world, as adaptation, & these changing affect each other, & their bodies, by certain laws of harmony keep perfect in these themselves.—instincts alter, reason is formed, & the world peopled with Myriads of distinct forms from a period short of eternity to the present time, to the future."

(Darwin, Notebook D. p.36, [see ref. de Beer, 1960])

In chapter three we begin to address the question of what constitutes the hallmark of a cohesive or harmonious society. Indeed are they the same thing? (As indicated earlier, communist states were often very cohesive, but were they in harmony?). The fundamental issue is to understand in what ways a society, such as London, may be cohesive or harmonious in a multi-cultural sense. And are these properties mutually exclusive?

1.2.3 Integration and Diversity

From harmony we turn to the question of diversity, i.e. to what degree does the homogeneity of a system dominate its behaviour? Basically, how much variation or asymmetry is required to create novel forms, whilst maintaining the cohesion of the system as a whole? This is a crucial question in our attempts to understand cohesion, especially, vis-à-vis social diversity and cultural homogeneity. Is there a critical level of diversity required in order to maintain evolvability and plasticity within a complex system? For example, monocultures proved to be demonstrably fragile during the agricultural revolution of the 20th century. Is the same true of human society? Is Japanese society strengthened or weakened by being a single culture? Is the inverse therefore true for a highly diverse multicultural society such as the United Kingdom?

One example we will consider in chapter three is the cultural mix evolving within the suburbs of North America. Here the cultural diversity is acting in many complex ways, to both enrich society, and simultaneously create segregated enclaves along political, religious and racial lines. The ultimate expression of this process is best portrayed in the Cyber-punk

literature, such as the novel *Snow Crash* by Neil Stephenson, where gated communities have evolved into '*Burbclaves*', which house completely ghettoized mini-cultures. The rise of the Internet and personal communication technologies are amplifying the driving forces behind these processes, but it remains to be seen how far this process will run. These topics are the focus of chapter three.

1.2.4 Tipping Points and Phase Transitions

One of the really tricky aspects of understanding complex systems is that they don't follow easily predicted paths. Typically they flow along nicely for a while and then jump suddenly into an entirely different state. The technical phrase to describe this is a "phase transition". It sounds abstract, but your mortgage repayments and the economy in general are often victims of just such a shift in market dynamics. The following is a brief technical description for those interested, or you can skip to the following section as it all makes sense later!

"A phase transition is an abrupt change in a systems behavior. A common example is the gas-liquid phase transition undergone by water. In such a transition, a plot of density versus temperature shows a distinct discontinuity at the critical temperature marking the transition point… In nonlinear dynamical systems, the transition from self-organizing to chaotic behavior is sometimes referred to as a phase transition (or, more specifically, as an order-disorder transition). The distinguishing characteristic of a phase transition is an abrupt sudden change in one or more physical properties. (Wikipedia, 2009)

This concept of a step change in a social system is well captured in the popular concept of a 'tipping point'. The text by Malcolm Gladwell (Gladwell, 2002) is of particular interest in this context. One example outlined by Gladwell is from modern US societies, where the relative percentage of professional couples has a marked impact on the wider stability and prosperity of the surrounding community. What is of interest is that it requires a relatively small percentage change in these social units to have a massively positive, or negative, impact on the local society. Another rather topical example is the ongoing credit crisis and housing market woes being experienced globally; (as of mid 2009.) The bursting of such economic

bubbles is a well-studied phenomenon, and research indicates that such processes demonstrate some of the properties of a phase transition, (simply on a larger scale than a boiling kettle (Haken, 2004.)

Politicians and economists often wish for a "soft landing" when the economy overheats, and they tweak interest rates and monetary policy in order to deliver this nice fluffy state of affairs. Unfortunately, the real economy is more like a 747 jumbo jet in mid-flight, and tweaking the rates is like giving the pilot only two big buttons marked up/down to press. He probably can land the plane, but 'soft' is not likely to be the right adjective! We return to this theme of transitions again within networks in chapter 2. (Actually a pilot did land a passenger jet once, using only his throttle to control his engines after the normal aileron control systems were destroyed by a missile over Baghdad: [http://wapedia.mobi/en/DHL_shootdown_incident_in_Baghdad].)

1.2.5 Exploitation vs. Exploration

Any society requires a degree of cultural homogeneity to provide a common context and trust between individuals. At the same time it also requires a flow of new knowledge, ideas, genes and social diversity in order to avoid stagnation and collapse. This effect is mirrored in all evolving physical systems, from ecosystems to commercial organizations. It has been most clearly described in the concise and excellent text *Harnessing Complexity*, (Axelrod and Cohen, 2000). This balance is also of interest in the design of computer programs that use a form of artificial evolution, termed Genetic Algorithms (GA) (Mitchell, 1998). In such GA models it becomes immediately obvious that a fine and difficult balance is required between shaping the population of evolving programs to the target problem, and allowing enough genetic diversity for the system to explore all of the problem space. This theme cuts across several chapters, but it is of most interest in the evolutionary development of societies and commercial enterprises. In commerce it is now an issue of basic survival to successfully balance the exploitation of existing offerings, against investment in research for new products, which is both costly and time-consuming. One of the less visible, but ultimately critical developments is the accelerating migration of R&D programmes from western states to the emerging BRIC countries. Across Asia, China and India state-of-the-art research facilities have been developed and invested in, by both governments and corporate groups. The power house of

21st century innovation will therefore be these new centres of thought. When coupled with the parallel total shift in manufacturing capability, this paints a desperate picture for the economic prosperity of many western states that have failed to sustain investment in their own research efforts. More on this topic is captured in chapter five.

1.2.6 Symmetry and Asymmetry

One well-studied aspect of the driving processes in complex systems is that of symmetry breaking. In particular most CAS frequently require some point of asymmetric interaction in order to enable work to be done and novelty generated. It appears to be a key to many processes of complex pattern formation; from snowflakes to Islamic carpets. (A useful introductory reference on the topic is the book, *The Self-Made Tapestry,* [Ball, 1999].) A useful example of trust and asymmetry comes from work in which small asymmetries in the pay-off matrix for a Prisoners Dilemma problem lead to highly complex spatial patterns (Nowak and May, 1992). We will return to this topic in chapter three. It is also interesting to see that for complex structures to emerge within a CAS, its constituent elements need to be in a state of imbalance. A question we might then ask is what does this imply for a society and the impact of cultural diversity?

1.2.7 Polarization and Differentiation

One of the most interesting aspects of cohesive systems is the spontaneous differentiation into complex sub-structures. The apex of this process is cell-differentiation in multicellular organisms. The transformation of a single cell into an elephant, or a bee, is a pretty cool trick. No, we don't understand the detail of how this is accomplished, even when we possess a genomic map for some organisms. The recent work by the systems biologist Denis Noble (Noble, 2008) beautifully illustrates the sheer complexity of the problem. An interesting example of this is the first cloned cat (Copycat!), which has marked variation in the patterns of its fur when compared to its genetically identical parent. As well as marked behavioural differences. Such examples deflate the misplaced belief that an organism's genes completely determine its condition and actions. This is especially important in the area of socio-biology, where vocal proponents such as Richard Dawkins, attempt to enshrine genes as the primary determinants of human evolution. The following

quote from Noble illustrates a more comprehensive perspective on the formation of life, than that advocated by the Neo-Darwinist camp:

"Much more than the genome is involved in the development of an organism. If there is a score for the music of life, it is not the genome, or at least not that alone. DNA never acts outside the context of a cell. And we each inherit much more than our DNA. We inherit the egg cell from our mother with all its machinery, including mitochondria, ribosomes, and other cytoplasmic components, such as the proteins that enter the nucleus to initiate DNA transcription. These proteins are, initially at least, those encoded by the mother's genes. As Brenner said, 'the correct level of abstraction is the cell and not the genome'." (Noble, 2008, p.41).

Finally, no text on complex systems and patterns can fail to mention the early work by Alan Turing on pattern formation in organisms and CAS (Turing, 1952.) In addition to laying the foundation of computer science and breaking German encryption ciphers, he also found time to do seminal work on equations that describe reaction-diffusion systems. Such equations describe how patterns emerge, from how the skin of a zebra displays stripes, to how spiral waves emerge in complex chemical reactions. The interest in such mechanisms is not that we may possess some theory for how complex patterns emerge from simple interactions, but that when they do the host structure can often retain its identity or function. Increasing differentiation is subsumed or incorporated within the adapting structure. We will be returning to the themes of polarization and differentiation in later chapters as they play a major role in group formation in CAS. It pertains to the question of why human populations become so easily polarized into opposing or conflicting groups. A number of researchers have recently addressed this issue and produced very detailed models, which may explain such behaviour, (Epstein *et al.*, 1996). This topic really matters, as human beings are still busy demonizing each other and planning genocide based on social polarization. Chapter three will look in detail at the historical consequences of this behavior in terms of the rise and fall of civilizations. Basically, these apparently abstract concepts often possess profound social consequences, for example, in the formation and isolation of multi-racial communities within the UK. We will return to this under the theme of societies and cultures.

1.2.8 Energy and Dissipation

All physical systems obey the second law of thermodynamics. Any composite system is continuously struggling to maintain its form and cohesion. To maintain structure an input of energy is required. It has been one of the longstanding mysteries of life that it appears to flagrantly violate this principle within localized regions of space-time. Like a stage magician, life conjures complex forms out of apparent thin air, using a sleight of hand to steal energy from the surrounding matrix of the universe. What is of interest in a social context is that energy and dissipation are also essential to the sustained existence of complex social structures. One example of the social dimension of this is in the sudden market shocks that periodically impact the global market. Economists rush to offer blasé explanations such as interest rates or oil price shifts, yet the cause may be an endogenous (internal) shifting of the forces at play in the system, with no single principal cause.

A far more useful question to ask is, do we need the destructive side of CAS? Are disruptive forces in fact essential to sustain change and evolvability in a finite system? This theme will be reflected upon throughout the book. A controversial and extreme example of this is the argument that wars are ultimately constructive, as they accelerate technological development and sweep away dysfunctional social/political organizational systems. The prime cited examples are the formation of the UN after World War II, and the League of Nations following the First World War. (The author's personal view is that there must be cheaper and less bloody methods to reshape human society.) One interesting analogy from biological systems is the process of apoptosis, within which cells in the body undergo a programmed self-destruction in order to preserve the overall functioning of the host organism. If a system has no mechanism for a phased renewal of its component parts then stasis or disintegration will result. Of course disambiguating these processes in the social context can be tricky. Is a revolution a state of violent chaos, or a useful mechanism for restructuring society into a renewed cohesive state?

1.2.9 Feedback

A precursor to Complex Systems was the field of Cybernetics, which originated in the 1940s in parallel with von Neumann's work on game theory. Cybernetics is of interest as it is a subject that gets continuously rediscovered every decade or so and given a new name! Each time the basic concept of a feedback driven system is studied, a new sub-field is spawned, yet the original

work on Cybernetics remains in essence as the foundation. One of the preeminent and most lucid early writers on the topic was W. Ross Ashby, a brilliant English psychiatrist and founder of Cybernetic thinking. A nice example, which sets the scene for our later consideration of Complex Adaptive Systems, can be taken from his classic text, *An Introduction to Cybernetics*:

"*Science stands today on something of a divide. For two centuries it has been exploring systems that are either intrinsically simple or that are capable of being analysed into simple components. The fact that such a dogma as "vary the factors one at a time" could be accepted for a century, shows that scientists were largely concerned in investigating such systems as allowed this method; for this method is often fundamentally impossible in the complex systems. Not until Sir Donald Fisher's work in the '20s, with experiments conducted on agricultural soils, did it become clearly recognised that there are complex systems that just do not allow the varying of only one factor at a time—they are so dynamic and interconnected that the alteration of one factor immediately acts as cause to evoke alterations in others, perhaps in a great many others. Until recently, science tended to evade the study of such systems, focusing its attention on those that were simple and, especially, reducible."* (Ashby, 1956, p.5).

His excellent book has now been made available online and can be found at http://pespmc1.vub.ac.be/ASHBBOOK.html.

The key point is that from control theory we understand that any system can only maintain stability (and hence structure) via a feedback loop. This applies equally to CAS and offers one basic method to understand their behaviour. Unfortunately, it appears to be frequently forgotten in the social sciences and economics. Even worse, and simply inexcusable, is the degree of ignorance within the military communities of the Western powers, who fail to understand that any action taken will lead to recursive and unpredictable consequences, due to complex and multiple feedback paths; (more on that in chapter two.) However, identifying the feedback paths and mechanisms within complex systems can be extremely difficult. If a company maintains healthy operation over many decades in the face of constant competition and bear markets, what are the key feedback processes that enabled it to survive? Was it focusing on profit, or a focus on strong social cohesion and morale within the organisation. (Gladwell's *The Tipping Point* (2002) provides some examples

of adaptive companies, as does the major reference work in the commercial domain, *Built to Last* (Collins and Porras, 2005).) This aspect will be illustrated in chapters four and five on technological and commercial development.

Another example of human feedback is the process of flood control. Major flooding occurs with increasing frequency as we attempt to engineer rigid flood defences and give rivers nowhere to go when they rise. Smart thinking says take down the levees, and give the river room to flood agricultural areas, where it will deposit useful silt anyway. This is a classic case where we mistakenly apply linear thinking to the management of a fundamentally complex adaptive system. The summer of 2007 again witnessed serious flooding across the UK. Why? Because we have neglected basic maintenance of the rivers and waterways. In politics, sewage and river dredging are very low priorities. (Even if dredging up political sewage on your opponents is a somewhat higher priority.)

1.2.10 Trust and Trustworthiness

A subtle, but vital dimension of complexity is a principle that primarily applies in the human social and political domains, i.e. that of trust between agents and institutions. It has corollaries in the physical sciences, but is of key interest as a force acting upon social systems. The author's guiding hypothesis is that inter-agent trust is a primary catalyst for social cohesion. Trust is the dynamic glue that binds the fabric of human society together, politically, socially and economically (Putnam, 2001, Fukuyama, 1995.) It is a key element in the evolution of human social structures from hunter-gatherers to city building civilizations. If this book conveys nothing else it is my intention to emphasize this point. That is, that trust, and the parallel quality of trustworthiness, are the very bedrock of cohesive human societies, in all dimensions of life, political - private, public, and commercial. We will allocate some time to developing the themes of trust and trustworthiness in the following chapters.

1.3 Book overview

This section briefly outlines the principal contents of the remaining chapters. This is a useful process from an educational perspective as it helps set the scene and provides some context as you read the text. (I also strongly recommend the study texts by Tony Buzan (Buzan, 2006), as they provide very practical and effective techniques for learning any subject. I therefore include some of Buzan's methods in the style and presentation of this text in order to make it more digestible, such as the use of mind maps at the end of each chapter, as an overview method.)

There are three common themes that thread the chapters together. The first of these is the effect of trust on the cohesion of systems. Second is the theme of bridges as a physical and literal metaphor for the linking together of disparate elements to build a cohesive whole. Third is the role of security and defence mechanisms within CAS as a force for sustaining cohesion. Of course this later theme also leads to violent disruption, but this will be part of the discourse as we progress.

Chapter 2 *Networks*

The second chapter introduces the important topic of network theory and its key role in many CAS. The study of network dynamics, topology and behaviour is currently very topical and many recent texts have addressed this subject, for example *Linked*, (Barabasi, 2003.) The text by Watts (Watts, 2004) is also an excellent introduction to the subject and recommended for any serious study of complex network systems. The need to include a chapter on the subject here is simply that it underlies so many of the arguments in the subsequent material on social, biological, and technological cohesion. For example, we will look at the cohesive role of networks in the domains of security and defence, social networks and in physical transport networks. We will also cover the distinction between physical and abstract networks, as each form plays multiple roles in binding complex systems together.

The chapter covers not just how networks transfer information across systems, but also how this information may be constructive or destructive, as in the case of violent conflicts. On a technical level the chapter aims to communicate some of the excitement that is driving a rapidly emerging

scientific field that has vast implications for how we design everything, from telecommunication networks to rail links and air routes. Of course the greatest exemplar of this is the Internet, which gets a section of its own and appears again in the exposition on technology in chapter four. There is some techie detail on network theory, feel free to skip it, if it doesn't float your boat! This is followed by a sub-theme on resilience and robustness in complex systems, which is more interesting and worth a dip. Finally we have a piece on the history of communication networks in warfare, which is of more general interest.

Chapter 3 *Societies and Collectives*

This chapter attempts to analyse the degree of social cohesion present both today and over the history of human civilization, (a somewhat non-trivial exercise.) The goal of this is to predict what future forms human collectives will take. In particular, we look briefly at the factors influencing the lifespan of several civilizations throughout history. Beginning with ancient Egypt, then Rome, China, the British Empire and finally studying the current hegemony of the USA. Specifically, are there some obvious signatures that characterize the emergence of a civilization and, more importantly, signs that signal its demise?

We then introduce the concept of modelling civilizations and societies using artificial computer-based agent simulations. Again, feel free to skip this part if it gets a bit too technical. It descends into an historical review of Artificial Intelligence for the purpose of introducing computer modelling of human societies. It also looks at the inherent limits of artificial models for understanding large-scale human activities. This is followed by the crux of the text, a review of the driving factors that impact the cohesion of current societies. We look at the major forces shaping family, political, religious and cultural cohesion. The chapter then looks at the topics of trust and consultation; as two of the thematic threads that hopefully bind the text into a whole.

The final section asks the pertinent question, what will be the lifetime of current western and oriental societies? Don't expect an answer to this, just the author's personal opinion, with a smattering of facts and figures to justify the

stance. At least you have been forewarned, unlike most texts that sell themselves on the pretext of offering the 'truth'. Escaping one's cultural roots is never an easy task, although, having travelled to over twenty countries, and lived and worked in China, I feel partly able to see beyond my immediate cultural horizon. (China is a land whose culinary achievements certainly broaden the occidental mind!)

Chapter 4 *Technology Nexus*

This chapter considers a number of technical developments in the telecommunications and computing domain, in order to illustrate how self-organizing processes can build highly complex structures from basic elements. Such structures may be defined as emergent. Hence the theme of interest is how technologies have shaped the structure and growth of human societies, in particular what makes communication and IT technologies such powerful catalysts for social change. Some of the key technologies and associated issues of interest that are touched upon are:

- Libraries and electronic webs
- Information Networks
- Computing
- Robots and Artificial Intelligence

The history of communications is reviewed from ancient times, as this illuminates the power of this process in human history. A particular emphasis is placed on the role of communication networks in warfare, as these represent the spear-head of human communication processes (pardon the pun!) The technology piece then flows from the communication domain, lasers, and silicon into computers, AI, the smart-phone, and software. The rationale for the treatment of these topics is the sheer scale of the impact they are having, i.e. the computing revolution makes all of the facets of globalization possible. These technology forces are also shaping the future in profound ways that we simply do not understand. As a fan of the Cyber Punk genre of fiction, I frequently turn to the works of William Gibson and Neil Stephenson in order to grasp the potential social consequences of the knowledge revolution.

The chapter also covers the issues surrounding security in the cyber age, as this has been the focus of the author's personal research for several years. In particular, it throws light on our understanding of what makes a network, or complex system, stable under attack conditions. For example, the way in which computer viruses mirror the behaviour of biological pathogens, has underscored the need for interdisciplinary research and the holistic nature of complex adaptive systems.

Finally, technology-driven networks are, of course, morally neutral. They can transmit spam, or porn, or even integrate military command networks. Alternatively, they are clearly enabling innovative new social interactions, (e.g. the Facebook, Twitter and MySpace effect), and lowering economic costs. We have not been at such a technological juncture, since the invention of movable type and the Gutenberg press around 1439. The full consequences of that revolution would have been equally impossible to foresee in the mid-15th century.

Chapter 5 *Corporate Cohesion*

The motivation for this chapter is to understand how companies form and dissipate. Again the twin themes of diversity and cohesion will be analysed in this context, as they have a significant impact on all aspects of commercial activity, from the size of companies to the degree of competition within a market. A number of sub-themes are also considered, including:

- Monopolies and mergers
- Optimization vs. resilience
- Globalization and networks
- Agent-based modelling of commerce
- The adaptive enterprise

The second point is of most interest, as it relates to the topic of cohesion across complex systems. Specifically, to what degree does any system require reserves of energy and resources in order to sustain itself? It appears to be a common principle in most organizations to use cost-cutting as a first line response to external pressure. The chapter then looks at transport and communication networks again, but from a commercial perspective. It ends

with a brief set of case studies that illustrate some of the techniques adopted by good companies that have enabled them to survive and grow. And conversely some examples of companies that have failed to adapt.

Chapter 6 *Conclusion: Building Bridges*

This summary chapter is an overview of cohesion and in particular expounds on the bridge theme for understanding cohesive forces. The aim is to show how a single overarching theme, i.e. cohesion can illuminate the domain of complex systems. Such an effect may be best defined as one of *consilience*. It looks at the dynamic balances inherent in CAS that leads to cohesive states, e.g. between security and stability, and growth versus decay. The contentious topic of social engineering is then reviewed and whether it is possible to engineer stable societies. This leads nicely into the domain of revolutions and the clash of civilizations.

We complete the chapter by then embarking on a visionary walk to divine possible future scenarios for human society in terms of our potential for cohesive development. In particular, we return to the importance of trust as a mechanism to reinforce the bonds of society. We may lose contact with terra firma at this point, but hopefully the previous six chapters contained enough pragmatic content for you to not ask for your money back!

1.4 Dreamers

We have spoken of principles, symmetry, forces and harmony. We will examine these at play in networks of all forms, both physical and social, and in engineering structures, such as bridges. In writing this work I was partly inspired by the lives of two men in particular, Isambard Kingdom Brunel and Buckminster Fuller. Both men embodied these same principles in their work and achievements. Brunel, the engineer supreme and master of ships, rail networks and bridges. Fuller, the dreamer and architect, whose geodesic domes, marked the transition in the 1950's from old-world design, to a new age of free-form structures, and were an embodiment of future vision. (As

such, they frequently crop up as city spanning domes in Sci-fi movies.) This section briefly reflects on elements from both of their lives, as they help frame the journey we are exploring. In particular, they echo the ethos of cohesion and structural harmony that we are seeking to capture.

Isambard Kingdom Brunel

At the beginning of the 19th century the world was still vast and disconnected. Not much had really happened for the preceding four millennia. Oh, we had put up a few pyramids and the Coliseum, and even printed the odd book, but our distant ancestors would still have felt quite at home, if they were magically transported through time to the year 1800. Yet within a mere century, the earth had moved. The same ancestors dropped in the year 1900, would have felt mind-numbing culture shock. As if by the wave of some omnipotent hand, humanity had mastered the physical world overnight. Little of the modern world that we see around us today did not have its roots or origin in the 19th century. (This includes the computer I am typing this on, as many would regard its grand-father, as the Victorian genius Charles Babbage.)

One of the leading architects of this world-shaking revolution was Isambard Kingdom Brunel. He achieved fame as the Chief Engineer of the first major river tunnel in the world; constructed under the Thames in London and completed circa 1843. As with many of Brunel's works, the tunnel was not an immediate financial success - it was first run as a shopping mall and tourist attraction, charging just a penny a visit. But, just like his vast iron ships, it proved the technology was possible, and others followed where he led. The tunnel was followed by bridges, the most amazing example of which, I feel, is the Maidenhead Railway Bridge over the Thames in Berkshire. This was the flattest, widest brick arch bridge in the world. What boggles the mind is that it is still carrying main-line trains to the west of England, over its two arches, with each span totalling 39 m, and a wide enough to carry four tracks. This supreme example of engineering now carries modern trains that are approximately 10 times as heavy as those of Brunel's age. Not bad for someone who infamously said:

"I am opposed to the laying down of rules or conditions to be observed in the construction of bridges lest the progress of improvement tomorrow might

be embarrassed or shackled by recording or registering as law the prejudices or errors of today."

(Isambard Kingdom Brunel)

Most men would consider the creation of the greatest tunnels and bridges in history a sufficient lifetime's achievement, but not Brunel. Brunel's vision was epic. He envisaged passengers purchasing a single ticket at London Paddington station, and then travelling from London to New York, changing from the Great Western Railway to The Great Eastern Steamship at the Terminus in Neyland, South Wales. So his next task was to design and create the greatest ships the world had ever seen. He started with the SS Great Western in 1837. The largest steamship in the world, it halved the journey time to New York from 34 to 15 days. Not good enough says Brunel, let's build an even larger all-iron ship with a propeller. The SS Great Britain could do the London to New York run in 14 days!

This still wasn't good enough, so Brunel built an iron ship 700 feet in length and able to sail to Australia and back without refueling, the SS Great Eastern. Unfortunately, as a passenger carrying ship it was a complete and utter disaster. In 1859 Brunel suffered a stroke and died just before the Great Eastern sailed for New York. Then on its maiden voyage, which was due to begin on 16th June 1860, once the passengers had boarded, the Captain announced they would not sail until the 17th as the crew were drunk! It's most valuable phase was probably towards the end of its service, when it was used as a cable-laying ship for the first successful transatlantic telegraph. This nicely brings us to the modern age of electronic communications, a point which we will return to in chapter four.

Buckminster Fuller

Fuller's life is one of early tragedy and later vindication as a visionary of the 20th century. It is a story that is infrequently told these days, which I feel is shameful, and this state of affairs will now be rectified here. Fuller was a maverick from childhood, always inventing new contraptions and seeking to push the boundaries of knowledge. In 1922 his first daughter died aged four from meningitis, a tragedy that nearly drove him to suicide. His first efforts at

establishing a new housing business ended in total bankruptcy, after which he determined to undertake a new quest and personal voyage. In his own words:

"In 1927, at age thirty-two, finding myself a "throwaway" in the business world, I sought to use myself as my scientific "guinea pig"...in a lifelong experiment designed to discover what – if anything – a healthy young male of average size, experience, and capability with an economically dependent wife and newborn child, starting without capital or any kind of wealth...or university degree, could effectively do that could not be done by great nations or great private enterprise to lastingly improve the physical protection and support of all human lives, at the same time removing undesirable restraints and improving individual initiatives of any and all humans aboard our planet Earth."

(Fuller, 1981, p.124)

He really liked long sentences! He was perpetually optimistic and travelled the globe incessantly, meeting and conversing with everyone he could. One of his lesser idiosyncrasies was to wear three wrist watches, one for the current zone, one for the zone he had departed, and one for the zone he was going to! His life is truly inspiring as an example of the difference a single human being can make through sheer force of will, and an optimistic vision of life. In relation to the cohesion theme, his principal contribution (one of many), the geodesic dome, is a brilliant example of structural beauty, harmony and balanced forces. In his major summary work, *Critical Path*, he explains how, as a young man he witnessed firsthand the succession of technological revolutions that were then birthing the modern world, such as the motor car and the first powered flight at Kitty Hawk.

"I was convinced that, unannounced by any authority, a much greater environmental and ecological change was just beginning to take place in my generation's unfolding experience than had occurred cumulatively between my father's, grandfather's, great-, and great-great-grandfathers four previous generations. I had read their diaries, expense accounts, or letters containing descriptions of their lives in their successive undergraduate days in the Harvard classes of 1883,1843,1801,and 1760, respectively. They all told of days-long walking or driving trips between Cambridge and Boston. I realized intuitively that the subway, which opened in my 1913 freshman year to connect

Harvard Square in Cambridge to Tremont and Park streets in Boston in seven minutes, was a harbinger of an entirely new space-time relationship of the individual and the environment." (Fuller, 1981, p.130)

Fuller clearly perceived the quantum shift in man's relation to the scale of the planet as a result of the revolution in communication and physical transport networks, that occurred at the beginning of the 20th century. He passionately believed in the future potential of humanity to achieve a prosperous and united world order. And, equally, that we stand at a treacherous crossroads in our potential evolution, depending on our capacity to embrace such a global vision.

His concept of tensegrity structures, such as the geodesic dome, is even now being applied in state-of-the-art examples of architecture. And in particular, it is being used in novel bridges, such as the new Kurilpa Bridge in Australia, which links us back to one of our sub-themes again, and the work of Brunel. (Tensegrity is a fascinating concept, a mash-up of the words tensional and integrity. It refers to structures with an integrity based on a synergy between balanced tension and compression components. In addition, biological structures i.e. muscles and bones, and even cell membranes at the micro-scale, are immensely strong due to the balance of tensioned and compressed parts. The muscular-skeletal system is hence a synergy of muscle and bone. (Wikipedia, 2009).) Fuller thought deeply in a holistic and systems oriented manner. He also thought big; really, really big, with detailed designs for mile-high towers, vast cities and mile-wide airships; (whimsically termed Cloud 9's)! Reading his works however, is not an easy task, due to his bizarre penchant for initiating new fused and twisted technical terminology; for example using 'world-around', rather than 'world-wide'. In an almost Descartes-like manner, he wished to fundamentally revise how people conceived of the world, and themselves, with new trigonometric projections for maps, linguistic expressions and engineering concepts. However, Fuller's story demonstrates that, as we will encounter in later chapters, one person can make a fundamental difference.

Summary

So we have raised some questions about the vexing issues of social cohesion and the evolution of human civilization. As ever, nature guards its

secrets with jealous care. Fortunately, we have the legacy of Turing, Von Neumann and many other great minds on hand, to draw on in our attempts to fathom the complex processes within the formation and dissolution of human societies. In charting this wild territory we can at least now construct microcosms within our desktop computers that may open vistas unreachable by the finite calculating might of the unaided human brain.

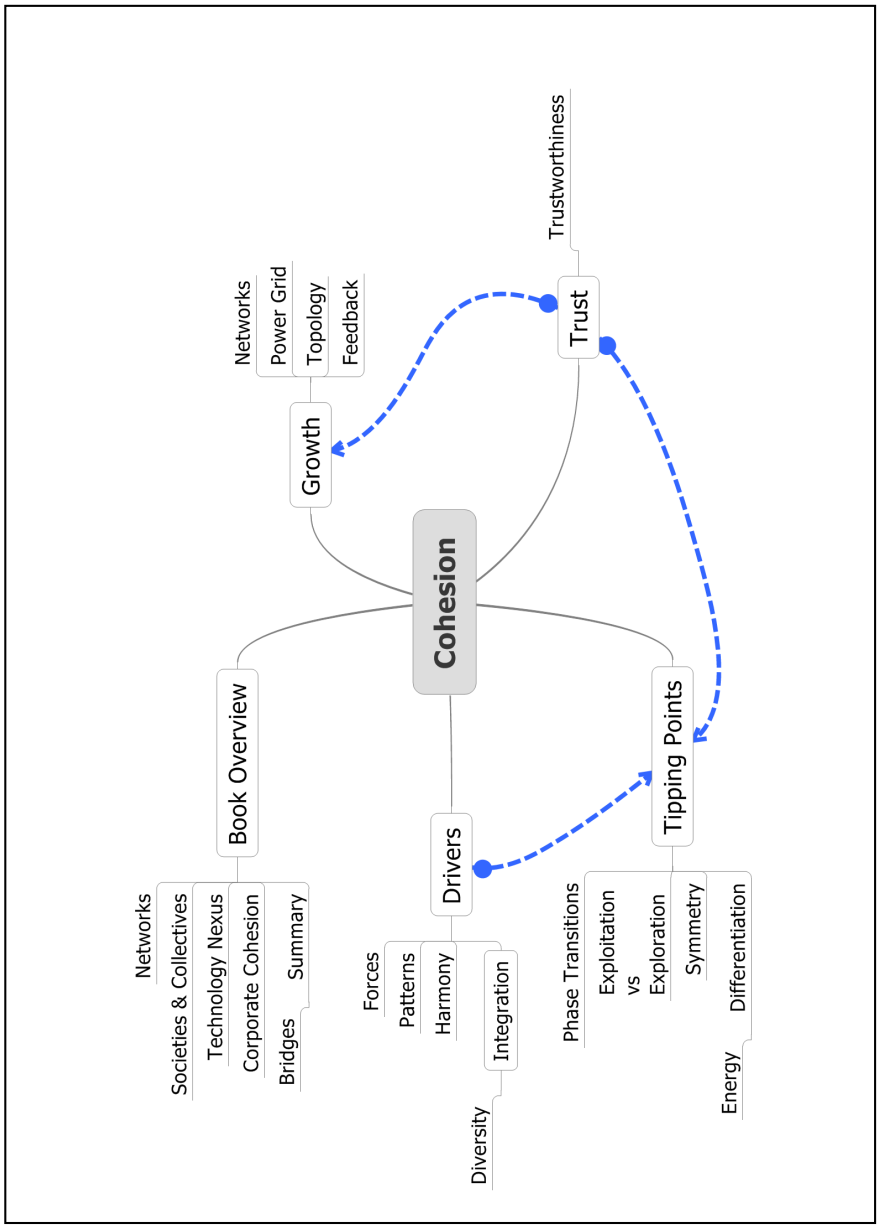
The motivation for the book is therefore to illuminate how complex social systems, via aggregation and self-organization, maintain their existence. The following chapters are designed to stimulate, entertain and occasionally provoke the reader. A number of questions can now be readily formulated that will act as the template for this book:

- What defines a cohesive system?
- How is any balance between attractive and repulsive forces achieved?
- What makes a coherent society, culture or company?
- And more importantly, can we engineer cohesive, (yet diverse), societies?

At this point a note of caution and modesty is required. These questions have troubled philosophers and scientists for millennia, and will almost certainly continue to do so for a long time to come. Consider this book as a route map, or tourist guide, to some of the more interesting or entertaining issues surrounding complexity and cohesion. A final word on the topic of bridges sets the scene for our journey:

"The bridge, behind him now, perhaps forever, is a medium of transport become a destination: salt air, scavenged neon, the sliding cries of gulls. He has glimpsed the edges of a life there that he feels is somehow ancient and eternal. Apparent disorder arranged in some deeper, some unthinkable fashion."

(William Gibson, *All Tomorrow's Parties*, p.273)



Mind map for chapter one.