THE DEATH OF ORDER AND DAWN OF COMPLEXITY: 21ST CENTURY POLITICS, ECONOMICS AND SOCIETY

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CHAPTER ONE: FROM ORDERLY TO COMPLEX SCIENCE

"The end of our foundation is the knowledge of causes, and secret motions of things: and the enlarging of the bounds of human Empire, to the effecting of all things possible"[i] Francis Bacon

"All science is either physics or stamp collecting"[ii] Ernest Rutherford

What is the Complexity Paradigm How and when did it emerge? Is it a hot new academic fad like globalisation or the end of history, or is it something more profound? To begin to answer these questions we need to jump back a few centuries and briefly discuss the emergence of what is various labelled as the Newtonian or linear paradigm. For reasons that will become clear, we have called it, the paradigm of order.

The Paradigm of Order

Although it has been said thousands of times before, it bears repeating, the Enlightenment was an astounding time for Europe. Relatively stagnate and weak and intellectually repressed by the Church during the so-called Dark Ages, intellectual energies released by the Renaissance came to fruition in the Enlightenment. During this time, Europe was reborn and became the centre of an intellectual, technical and economic transformation. It had an enormous impact on the way life is viewed at all levels from the mundane to the profound. Science was liberated from centuries of control by religious stipulations and blind trust in ancient philosophies. Rene Descartes (1596-1650) and, slightly later, Sir Isaac Newton (1642-1727) set the scene. The former advocated rationalism while the latter unearthed a wondrous collection of fundamental laws. A flood of other discoveries in diverse fields such as magnetism, electricity, astronomy and chemistry soon followed, injecting a heightened sense of confidence in the power of reason to tackle any situation. The growing sense of human achievement led the famous author and scientist Alexander Pope to poeticise, "Nature, and Nature's laws lay hid in night. God said *Let Newton be!* And all was light"[iii]. Later, the 18th century French scientist and author of *Celestial Mechanics* Pierre Simon de Laplace (1749-1827) carried the underlying determinism of the Newtonian framework to its logical conclusion by arguing that, "if at one time, we knew the positions and motion of all the particles in the universe, then we could calculate their behaviour at any other time, in the past or future"[iv].

The subsequent phenomenal success of the industrial revolution in the 18th and 19th centuries, which was based on this new scientific approach, created a high degree of confidence in the power of human reason to tackle any physical situation. By the late 19th and early 20th century many scientists believed that few surprises remained to be discovered. For the American Nobel Laureate, Albert Michelson (1852-1931), "the future truths of Physical Science are to be looked for in the sixth place of decimals"[v] From that time onwards, physicists would merely be filling in the cracks in human knowledge. More fundamentally, the assumption and expectation was that over time the orderly nature of all phenomena would eventually be revealed to the human mind. Science became the search for hidden order.

By and large, that vision of the universe survived well into the twentieth century. In 1996 John Horgan, a sernior writer at *Scientific American*, published a bestselling book entitled *The End of Science* which argued that since science was linear and all the major discoveries had been made, then real science had come to an end. All that was left was “ironic science” which:

does not make any significant contributions to knowledge itself. Ironic science is thus less akin to science in the traditional sense than to literary criticism – or to philosophy[vi].

Siimilarly, the eminent biologist and Pulitzer prize winner, Edward O. Wilson argued in his bestselling book *Consilience* (1999) that all science should be unified in a fundamentally linear framework based on physics:

The central idea of the consilience world view is that all tangible phenomena, from the birth of stars to the workings of social institutions, are based on material processes that are ultimately reducible, however long and tortuous the sequences, to the laws of physics[vii]

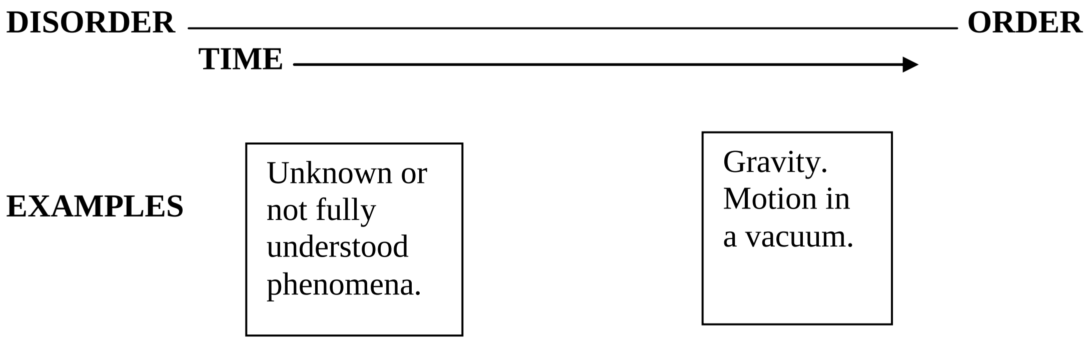
The linear view of the world prospered not only in sciences, but in the fundamental nature of Western social and political life.

To simplify drastically, the paradigm of order was founded on four golden rules:

- *Order:* given causes lead to known effects at all times and places.
- *Reductionism*: the behaviour of a system could be understood, clockwork fashion, by observing the behaviour of its parts. There are no hidden surprises; the whole is the sum of the parts, no more and no less.
- *Predictability*: once global behaviour is defined, the future course of events could be predicted by application of the appropriate inputs to the model.
- *Determinism*: processes flow along orderly and predictable paths that have clear beginnings and rational ends.

From these golden rules a simple picture of reality emerged.

Figure 1: Phenomena in the Paradigm of Order



Given the golden rules and picture of reality, several expectations emerged**:**

- Over time as human knowledge increases, phenomena will shift from the disorderly to the orderly side.

- Knowledge equals order. Hence, greater knowledge equals greater order.

- With greater knowledge/order humans can increasingly predict and control more and more phenomena.

- There is an endpoint to phenomena and hence knowledge

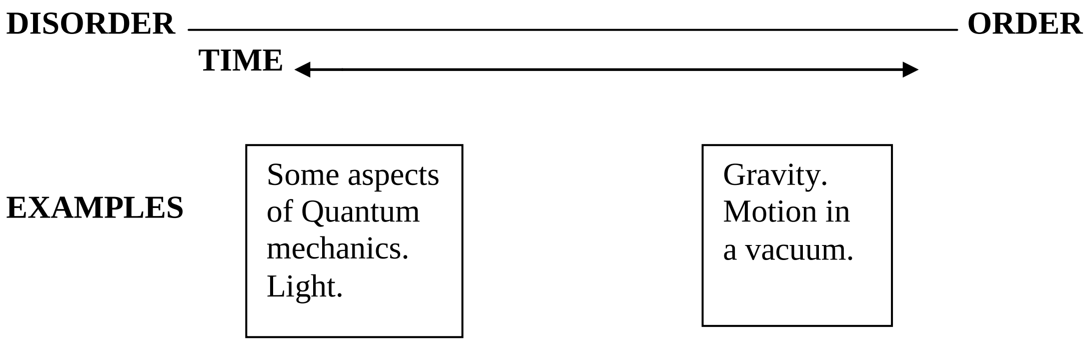
The orderly paradigm worked remarkably well and was conspicuous by incredible leaps in technological, scientific and industrial achievements. Science became orderly and hierarchical with clear divisions that manifested themselves in the departmentalised evolution of modern universities. Not surprisingly, success in these areas had a profound effect on attitudes in all sectors of human activity, spreading well beyond the disciplines covered by the original discoveries.

Spreading Ripples of Doubt

Certainty and predictability for all, the hallmarks of an orderly frame of mind, were too good to last. Fissures had existed for some time, even Issac Newton and Christiaan Huygens in the 17th century couldn't agree on something as fundamental as the nature of light (is it a particle or a wave?). These difficulties bubbled under the surface of acceptable scientific discourse and the expanding university arenas. They were often seen as unimportant phenomena that would be resolved by the next wave of emerging fundamental laws. However, by the early 20th century they could no longer be ignored. Henri Poincaré (1854-1912), the supreme physicist of his age, was one of the first to voice disquiet about some contemporary scientific beliefs. He advanced ideas that predated chaos theory by some seventy years[viii]. Later, Einstein's (1879-1955) theory of relativity, Neils Bohr's (1885-1962) contribution to quantum mechanics, Erwin Schrödinger's (1887-1961) quantum measurement problem, Werner Heisenberg's (1901-1976) uncertainty principle and Paul A. M. Dirac's (1902-1984) work on quantum field theory all played a decisive role in pushing conventional wisdom beyond the Newtonian limits that enclosed it centuries before. These scientists, all Nobel laureates, set in motion a process that eventually transformed attitudes in many other disciplines.[ix]

The new discoveries did not disprove Newton. Essentially, they revealed that not all phenomena were orderly, reducible, predictable and/or determined. For example, no matter how hard classical physicists tried they could not fit the dualistic nature of light as both a wave and a particle into the orderly classical system. Heisenberg's uncertainty principle, which shows that one can either know the momentum or position of a sub-atomic particle, but not both at the same time, presents an obvious problem for the orderly paradigm. Or, the paradox of Schrodinger's Cat experiment, which demonstrated the distinctive nature of quantum probability, again broke the fundamental boundaries of the former order. What this meant was that even at the most fundamental level some phenomena do conform to the classical framework, others do not. With this, the boundaries of the classical paradigm were cast asunder. Gravity continued to function and linear mechanics continued to work, but it could no longer claim to be universally applicable to all physical phenomena. It had to live alongside phenomena and theories that were essentially *probabilistic*. They do not conform to the four golden rules associated with linearity: order, reductionism, predictability and determinism. Causes and effects are not linked, the whole is not simply the sum of the parts; *emergent properties* often appear seemingly out of the blue, taking the system apart does not reveal much about its global behaviour, and the related processes do not steer the systems to inevitable and distinct ends.

Figure 2: Phenomena in the Paradigms of Disorder and Order



Given these non-linear phenomena and non-adherence to the golden rules of order, new expectations were necessary for this expanding paradigm**:**

- Over time human knowledge may increase, but phenomena will not necessarily shift from the disorderly to the orderly.

- Knowledge does not always equal order. Greater knowledge may mean the increasing recognition of the limits of order/knowledge.

- Greater knowledge does not necessarily impart greater prediction and control. Greater knowledge may indicate increasing limitations to prediction and control.

- There is no universal structure/endpoint to phenomena/knowledge

It is important to note that the shift in scientific analysis from utter certainty to considerations of probability was not accepted lightly. Schrodinger had originally designed his cat experiment as a way of eliminating the duality problem! The sea change radiated slowly outwards from quantum mechanics' domain of sub-atomic particles. Naturally, there was a wide schism between the exclusive niches occupied by leading particle physicists and mathematicians, on the one hand, and the rest of the scientific community, on the other. High specialisation meant that even scholars involved in the same discipline were not immediately aware of discoveries being made by their colleagues. Moreover, the language of science itself became almost unintelligible beyond a select circle of specialists. In any case, their intriguing speculations were not thought at first to be of everyday concern. Nevertheless, uncertainty was eventually recognised as an inevitable feature of some situations. In effect, the envelope of orderly science was expanded to add complex phenomena, also know as *complex systems*, to those already in place.

Complex systems in an Abiotic World

Once the door was open to probability and uncertainty, a new wave of scientists began studying phenomena that had previously been ignored or considered secondary or uninteresting, Rutherford's "stamp-collecting" activities.[x] Weather patterns, fluid dynamics and Boolean networks were just three of the areas that saw the growing acceptance of non-linear complex phenomena and systems. For example, one of the earliest people to conceptualise and model a non-linear complex system was an American meteorologist, Edward Lorenz.[xi] Lorenz developed a computer programme for modelling weather systems in 1961. However, to his dismay due to a slight discrepancy in his initial programme, the programme produced wildly divergent patterns. How was this possible? From an orderly linear framework, small differences in initial conditions should only lead to small differences in outcomes. But, in Lorenz's programme, small discrepancies experienced feedback and reinforced themselves in chaotic ways producing radically divergent outcomes. Lorenz called this the phenomena where small changes in initial conditions lead to radically divergent outcomes in the same system the "butterfly effect", arguing that given the appropriate circumstances a butterfly flapping its wings in China could eventually lead to a tornado in the USA. Cause did not lead to effect. Order was not certain. Chaos/complexity was an integral part of physical phenomena. Moreover, phenomena could not be reduced and isolated, but had to be seen as part of larger systems.

Other examples of complex systems can be found in simple forms of fluid dynamics. For example, the water molecules creating a vortex in your bathtub is a type of abiotic complex system. The molecules self-organise and form a stable complex system so long as the water lasts in the bathtub. The vortex is easy to recreate, but the exact combination of water molecules that made the specific vortex would be virtually impossible to recreate. Each vortex, though similar, is not an exact copy of the other. Another case is the movement of heated fluid in a contained space. As the fluid is heated it begins to organise itself into cylindrical rolls, heated fluid rising on one side and cooling on the other (the process of convection). However, when more heat is added instability ensues and a wobble develops on the rolls. Add even more heat and the flow becomes wild and turbulent[xii].

One of the most famous and simple examples of this type of fluid based complex systems is the Lorenzian Waterwheel. This is a wheel which pivots around a centrepoint and has hanging buckets at the wheel's rim. The buckets have holes in the bottom. Water is poured in from the top. If the flow of water is too low, the bucket will not fill, friction will not be overcome and the wheel will not move. Increase the flow, the buckets will fill and the wheel will spin in one direction or another. However, increase the flow to a certain point and the buckets wont have time to empty on their upward journey. This will cause the spin to slow down and even reverse at chaotic intervals. In this way, even a simple linear mechanical system can exhibit chaotic non-linear behaviour.

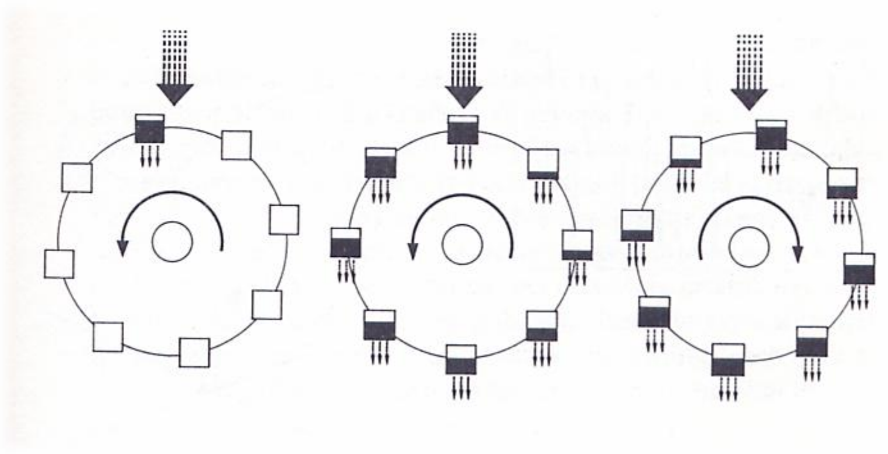


Figure 3. The Lorenzian Waterwheel[xiii]

This systems approach led to the creation of a variety of definitions of Complex Systems. In the abiotic world these systems are described as being *complex*, because they have numerous internal elements, *dynamic*, because their global behaviour is governed by local interactions between the elements, and *dissipative*, because they have to consume energy to maintain stable global patterns. Abiotic complex systems obey fundamental physical laws, but not in the same way as orderly linear systems. For example, the second law of thermodynamics, the most fundamental law of nature, states that when a system is left alone it drifts steadily into disorder. The effects of the second law are plain to see. A deserted building, for instance, eventually turns into a pile of rubble. After a few centuries even the rubble disappears without a trace. Ultimately, a system cut off from the outside world will fall into a deathly state of equilibrium in which change does not occur. For the complexity physicist Peter Allen, orderly equilibrium systems are “dead” systems[xiv].

Orderly linear systems are found at or near equilibrium. A ball bearing inside a bowl is a classic example; it quickly settles at the bottom and that is that. These systems can be very complicated. A jet engine is a wonderfully complicated piece of orderly machinery creating highly predictable physical outcomes that millions of pilots and passengers successfully depend upon every year. Complexity, by contrast, is exhibited by systems that are far from equilibrium. In this instance, the system has to exchange (dissipate) energy, or matter, with other systems in order to acquire and maintain self-organised stable patterns. That is the only option open to it to avoid falling into the destructive clutches of the second law of thermodynamics. The most dramatic illustration of that process is planet Earth. Without the nourishing rays of energy from the Sun, Earth would perish into complete equilibrium, and therefore nothingness. Continuous supply of energy from the Sun keeps the planet in a highly active state far from equilibrium. The energy is absorbed, dissipated and used to drive numerous local interactions that in total produce the stable pattern that we perceive as life on Earth. [xv]

Figure 4: The Range of Abiotic Phenomena in a Complexity Paradigm

DISORDER —— **COMPLEXITY** —— **ORDER**

Range of abiotic complex systems

EXAMPLES

Some aspects of Quantum mechanics and Light	Fluid dynamics. Weather patterns	Gravity. Motion in a vacuum.

Golden rules for abiotic systems in a complexity paradigm:

- *Partial Order*: phenomena can exhibit both orderly and chaotic behaviours.
- *Reductionism and Holism*: some phenomena are reducible others are not.
- *Predictability and Uncertainty*: phenomena can be partially modelled, predicted and controlled.
- *Probablistic*: there are general boundaries to most phenomena, but within these boundaries exact outcomes are uncertain.

Complex systems in the biotic world

By the later half of the 20th century, with complexity already deeply penetrating the physical sciences, biologists, geneticists, environmentalists and physiologists also began to consider their respective disciplines within the context of complexity.[xvi] Analysts in these fields set out to investigate the properties of systems, including human beings, comprised of a large number of internal parts that interacted locally in what looked like a state of anarchy that somehow managed to engender self-organised, stable and sustainable global order. These systems were not only complex, dynamic and dissipative, but also adaptive and display *emergent properties* or *emergence*.

In the words of Murray Gell-Man, a Nobel prize-winning physicist, “turbulent flow in a liquid is a complex system… But it doesn’t produce a schema, a compression of information with which it can predict the environment”[xvii]. Without that schema, non-biological systems cannot respond to their environments in anything other than orderly, disorderly or abiotically complex ways. The ability of biotic complex systems to adapt and evolve creates a whole new range of complex outcomes. Likewise, biological complex system are able to develop new emergent properties that may reshape the complex system as a whole and/or the sub-units that make up the system. As Coveney and Highfield argue: “Life is also an emergent property, one that arises when physiochemical systems are organized and interact in certain ways”[xviii].

From this perspective a whole new range of biotic complex systems began to be studied. For example, S, Kauffman was one of the first to view the genetic code as an evolving complex system.[xix] Other concepts like autopoiesis, symbiosis and the *Gaia* system emerged to challenge the orderly framework in the biological sphere[xx]. Due to the emergent nature of biological systems, the level of complexity can be significantly higher than those of abiotic phenomena and systems. Hence, on our simple scale of complexity biotic complexity is placed on the more disorderly side of the scale than biotic complexity.

FIGURE 5: The Range of Abiotic and Biotic Phenomena

DISORDER —— **COMPLEXITY** —— **ORDER**

Biotic Complexity	**Abiotic Complexity**

Range of abiotic/biotic complex systems

EXAMPLES

Some aspects of Quantum mechanics and light	Plant and animal interaction/ evolution. *Gaia*	Fluid dynamics. Boolean networks. Weather patterns.	Gravity. Motion in a vacuum.

Golden rules of biotic systems in a complexity paradigm:

- Partial Order: phenomena can exhibit both orderly and chaotic behaviours.
- Reductionism and Holism: some phenomena are reducible others are not.
- Predictability and Uncertainty: phenomena can be partially modelled, predicted and controlled.
- Probablistic: there are general boundaries to most phenomena, but within these boundaries exact outcomes are uncertain.
- Emergence: they exhibit elements of adaptation and emergence.

A simple example of a biotic complex system would be the evolution of a species or the interaction of a given plant or animal in a particular ecosystem. A fish in a small pond will evolve and interact with the various food sources (small plants and animals) in the pond to create a stable complex system (such as a stable total number of fish). However, if a change is introduced to the system, a new competitor or food source, the fish may adapt and alter the nature of the system in totally unforeseen ways. Over time, new emergent properties may evolve in the system and/or in the fish itself.

A larger example is that of the concept of *Gaia*. As summarised in Coveney and Highfield:

> *In 1968 James Lovelock upset gene-centered proponents of Darwin's views by arguing that the earth was not a ball of rock with a green layer of life on the surface. Biologists, following Darwin, see life adapting to its environment. The independently minded Lovelock viewed life and the environment as part of one superorganism in which creatures, rocks, air, and water interact in subtle ways to ensure that the environment remains stable… feedback mechanisms are invoked to explain the relative constancy of the climate, the surprisingly moderate levels of salt in the oceans, the constant level of oxygen over the past few hundred million years, and why life forms are so diverse. Like it or hate it, simply looking for Gaia can give new insights into the complex feedback systems that rule the planet.*[xxi]

Orderly (Modernist) and Disorderly (Postmodernist) Social Science

The success of the orderly linear paradigm in the natural sciences had a profound effect on attitudes and practices in all sectors of human activity, spreading well beyond the disciplines embraced by the original scientific discoveries. The social sciences were no exception. Surrounded by the technological marvels of the industrial revolution which were founded on a Newtonian vision of an orderly, clockwork universe driven by observable and immutable laws, it did not take much of an intellectual leap to apply the lessons of the physical sciences to the social realm. The English philosopher Thomas Hobbes (1588-1678) used Newton's mechanistic vision to shape an orderly society, a *Leviathan,* that would save it from chaos and civil war. The French economist Francois Quesnay (1694-1774) and the *physiocrates* modelled the economic system on a mechanical clock. The French mathematician, philosopher and revolutionary politician, Condorcet (1743-1794) wrote while imprisoned by the Committee of Public Safety:

> *The sole foundation for belief in the natural sciences is the idea that the general laws directing the phenomena of the universe, known or unknown, are necessary and constant. Why should this principle be any less true for the development of the intellectual and moral faculties of man than for other operations of nature?*[xxii]

The famous British economist Adam Smith (1723-1790) claimed to have captured the laws of economic interaction while his follower, David Ricardo (1772-1823) believed that some economic laws were "as certain as the principles of gravitation"[xxiii]. Karl Marx (1818-1883) wedded his vision of class struggle to an analysis of the capitalist mode of production to create the "immutable" and deterministic laws of capitalist development. Academics in all the major fields of social science welcomed the new age of certainty and predictability with open arms. Economics, politics, sociology all became "sciences", desperate to duplicate the success of the natural sciences. Moreover, this desire was institutionalised through the development of modern universities that created and reinforced the disciplinarisation and professionalisation of the social sciences.[xxiv]

The high point of the linear paradigm was reached in the 1950s and 60s, particularly in universities in the United States. Strengthened by the success of planning programmes during WWII and the early post-war period, pressured by the growing Cold War, and lavishly funded by the expanding universities, American academics strived to demonstrate, and hence control, the presumedly rational nature of human interaction. This traditional Newtonian approach was clearly expressed in the modernisation theories of the Third World development, the realist vision of international relations, the behaviouralist writings of sociologists, the positivist foundations of liberal economics and the rational plans of public policy experts and urban planners.

Using the Newtonian frame of reference modern social scientists unjustifiably assumed that physical and social phenomena were primarily linear and therefore predictable. They, consequently, applied reductionist methods founded on the belief that stable relationships exist between causes and effects, such as the assumption that individual self-interest is an explanation and/or a model for national level self-interest. Furthermore, based on this linear thinking they assumed that society and social institutions had an "end-state" towards which they were evolving. Hence, economic interaction, democracy, fundamental social orders (communism, capitalism, development), etc. all had final stages towards which they were evolving. Nation-states, societies and even individuals could be positioned along this developmental pathway and policies could be devised to help them towards the next level.

The cultural embodiments of the orderly paradigm evolved in a variety of forms, ranging from Sherlock Holmes to *Star Trek*. Like a good linear social scientist, Holmes' "scientific" study of crime enables him to solve all cases and astound his observers. A similar belief in human rational capabilities underlies *Star Trek*'s philosophy of "to boldly go where no man has gone before". In one episode from the 1960s series after the crew of the Enterprise have solved a local planetary difficulty, one crewmember was concerned that the planet will revert to its former violent ways. The captain calmly responds that some "sociologists" will be sent down to the planet to make sure that the problem wont happen again. The parallels to US "advisors" in Vietnam or IMF/World Bank advisors in the Third World are all too obvious.

The remarkable dominance of the Newtonian frame of reference is brilliantly captured by a quotation from an early critic of the "scientific" approach in politics argued in 1962:

> *So deep and widespread is the belief, so eminent and able the believers in the value of the contemporary scientific study of politics, that there is not a little impatience with any attempt to question it… All of us who profess the study of politics are confronted with the prevailing scientific approach, no matter how practical our concern, how slight out interest in methodology, or how keen our desire to get on with the business of direct investigation.*[xxv]

The notable international success of Francis Fukuyama's book, *The End of History and the Last Man* (1993)[xxvi], which claimed that history had reached its endpoint, demonstrated the continued influence of the linear framework. As Figure 5 summarises, orderly social science rest on the same foundation as orderly natural science, treated human beings like orderly atomistic objects and drew similar orderly conclusions.

Figure 6: The Foundations of Orderly (modernist) Social Science

Theoretical basis:

- Order
- Reductionism
- Predictability
- Determinism

Ontological/Epistemological Expectations:

- Over time as human knowledge increases, phenomena will shift from the disorderly to the orderly side. *Social scientists are able to understand more and more about society and humanity.*

- Knowledge equals order. Hence, greater knowledge equals greater order. *Thus, history is progressive, leading to greater order.*

- With greater knowledge humans can increasingly predict and control more and more phenomena. *Those with greater knowledge can know more and thus should be in control.*

- There is an endpoint to phenomena and hence knowledge. *Once this endpoint is reached history stops and societal change comes to an end.*

- There is a hierarchy of scientific knowledge and methods with the orderly natural sciences at the zenith. Duplicating this knowledge and methods is the justification of orderly social science.

Methodological Implications:

- Researchers look for rational foundations to all phenomena.

- There are no inherent limits to human knowledge. The only constrains are effort and technology.

- Researchers can obtain predictable and repeatable experimental results

- Duplicating orderly natural science methods is the primary methodological strategy.

- The creation of universal and parsimonious social laws is the ultimate goal.

Range of outcomes for the Paradigm of Order

DISORDER ———————————— **ORDER**

TIME ————————————→

(Over time, social phenomena will move from disorder to order)

However, even at its peak countervailing tendencies in the social sciences survived. There is nothing new about questioning the fundamental order and rationality of human existence. Debates over theses issues are easily traced back to Plato and Aristotle.[xxvii] A belief in the fundamentally rational and orderly nature of human existence only emerged in the Western philosophical tradition in the 17th and 18th centuries. Before this period, much of the human and physical world embraced unknowable mysteries that were cloaked in the enigmas of religion. During the 18th, 19th and 20th centuries, there continued to be a huge variety of potent critics of the mechanistic view and nature and society and of the limits of human rationality. In the late 18th century, the German scientist and philosopher, Immanuel Kant (1724-1804) argued that an organism, "cannot only be a machine, because a machine has only moving force; but an organism has an organising force… which cannot be explained by mechanical motion alone"[xxviii]. These arguments plus the work of Friedrich Schelling (1775-1854) who described an organic "science of living" and the writings of Goethe (1749-1832) who saw the mechanistic model of nature as "grey… like death… a ghost and without sun"[xxix] created the foundation of the German romantic philosophy of nature which rejected the mechanism of Newton. In the early 20th century, the hermeneutical tradition of Sigmund Freud (1865-1939) and Max Weber (1864-1920) challenged the belief in the human rational capabilities and the degree to which humans can understand and control their environment and societies. In the mid-20th century, the American philosopher John Dewey (1859-1952) was espousing his philosophy of pragmatism as a strategy for dealing with the limits of knowledge and uniqueness of human experience. In the 1960s the famous Austrian economist F. A. Hayek (XX-XX) argued that: "in the field of complex phenomena the term 'law' as well as the concepts of cause and effect are not applicable".[xxx] By the 1970s, the influential French post-modernist philosopher Jean-Francois Lyotard, in *The Postmodern Condition: A Report on Knowledge* was arguing for an end to all "grand narratives" of Western society. Consequently, from the 1970s onwards as social scientists continually failed to capture the 'laws'[xxxi] of society and economic interaction and were continually frustrated over their inability to do so, they began to significantly question the Newtonian framework that underpinned political thinking on the left and right.

Out of this emerged the extremely diverse, but significant challenge of (disorderly) post-modern position in social science. As defined by Terry Eagleton:

> *Postmodernism… is a style of thought which is suspicious of classical notions of truth, reason, identity and objectivity, of the idea of universal progress or emancipation, of single frameworks, grand narratives or ultimate grounds of explanation. Against these Enlightenment norms, it sees the world as contingent, ungrounded, diverse, unstable, indeterminate, a set of disunified cultures or interpretations which breed a degree of scepticism about the objectivity of truth, history and norms, the givenness of natures and the coherence of identities*.[xxxii]

As excellently summarised by Colin Hay (2002), the postmodernist position stands in direct contrast to the traditional orderly (modernist) social science position. As we shall see this drove postmodernists towards a strong "anti-naturalist" position, seeing the study of society and humans as something entirely distinct from the study of nature and the physical world.

Figure 7: The Foundations of Disorderly (Postmodern) Social Science [xxxiii]

Ontological Position

- The world is relational and experienced differently
- Such experiences are culturally and temporally specific
- Such experiences are singular and unique
- They are neither linked by, nor expression of, generic processes

Epistemological Position (Radical scepticism)

- Different subject-positions inform different knowledge-claims
- Knowledge is perspectival and different perspectives are incommensurate.
- Truth claims cannot be adjudicated empirically
- The assertion of truth claims are dogmatic and potentially totalitarian

Methodological Position (Deconstruction)

- Undermine strong knowledge claims.
- Undermine modernist assumption of a privileged access to reality that is untenable and potentially totalitarian in its effects
- Use deconstructivist techniques to disrupt modernist meta-narratives, drawing attention to otherwise marginalized ‘others’.

Range of Outcomes for the post-modernist Paradigm of Contested Order (Disorder)

- Multiple contested relational “orders” which rise and fall over time, but have no developmental path or direction.

It is important to note that postmodernism, by its own disorderly nature, has never been as structured and coherent as the modernist paradigm. Moreover, postmodernists anti-naturalist tendencies have generally kept them at arms-length from the natural and physical sciences. Hence, the postmodernist critique has mainly occurred within the social sciences. Despite these limitations it has had a profound impact on the social sciences forcing many in such diverse fields as international relations, political science and sociology (refs to this) to address its fundamentally disorderly and irrationalist arguments. In general, however, other fields, particularly economics, have held on tightly to the linear Newtonian framework, while others drifted towards a middling position between the extremes of a strictly scientific Newtonian framework and the fundamentally irrationalist reflectivist one.[xxxiv] It is this division and debate that has led the social sciences to the threshold of a 'scientific revolution' that could shift them into a complexity paradigm.

Complexity and Social Science

The next question to ask is, how do human beings fit into the complexity paradigm? They are an obvious symbiotic part of the complex web of their physical and biological surroundings. Nevertheless, what makes them distinct from this environment? There most fundamental difference is consciousness. The ability to ask “who am I?”, “How did I get here?”, “What does life mean?”. This ability to be selfaware, to understand aspects of the world around them, be aware of their history and to evolve interpretations of themselves, their surroundings and their history makes human beings fundamentally different from all other life forms and physical phenomena. However, this interpretive ability does not produce orderly interpretations. The uniqueness of individual human experience combined with multitudinous possibilities of collective human interaction and the evolutionary nature of human society produce a very high degree of complex interpretive outcomes. Therefore, conscious interpretive outcomes (norms, values, historical interpretation) must be positioned on the more disorderly side of our complexity scale. This does not imply that there are no universal norms, values or interpretations. For example, a prohibition against murder is a common societal trait. However, the definition of murder, the mitigating circumstances which could surround it and the punishment for the act all vary widely over time and between different societies and cultures. The position of conscious phenomena is outlined in Figure 7.

Figure 8: The Range of Abiotic, Biotic and Conscious Phenomena

DISORDER ——— **ORDER**

Alinearity	**Conscious Complexity**	**Biotic Complexity**	**Abiotic Complexity**	**Linearity**
	Range of non-linear dynamic systems			
Aspects of quantum mechanics and light.	Norms. Values. Language Narrative	Plant/animal interaction and evolution.	Fluid dynamics and weather patterns.	Gravity. Motion in a vacuum.

Golden rules of conscious systems in a complexity paradigm:

- *Partial Order*: phenomena can exhibit both orderly and chaotic behaviours.
- *Reductionism and Holism*: some phenomena are reducible others are not.
- *Predictability and Uncertainty*: phenomena can be partially modelled, predicted and controlled.
- *Probablistic*: there are general boundaries to most phenomena, but within these boundaries exact outcomes are uncertain.
- *Emergence*: they exhibit elements of adaptation and emergence.

- *Interpretation*: the actors in the system can be aware of themselves, the system and their history and may strive to interpret and direct themselves and the system.

Complexity theory does not disprove the rationalist paradigm or its antithesis (reflectivism), but acts like a synthesis or bridge between the naturalism of rationalism and the anti-naturalism of reflectivism and creates a new framework which bridges the two opposing positions. Both orderly rationalism and disorderly reflectivism are equally flawed. Both assume that humanity and its relationship to the natural are inherently orderly or disorderly when in reality they are both. This bridging position is summarised in the following table.

TABLE 1: Summary of fundamental positions of Modern, Complexity and Postmodern Science

Modern	Complexity	Postmodern
Epistemological position:		
Order	Partial order	Relational
Rationality	Bounded rationality	Relational rationality
Predictability	Predictability and uncertainty	Unpredictable
Reductionism	Reductionism and holism	Irreducible
Determinism	Probablistic and emergent	indeterminate
Non-interpretive	Interpretive	Relational interpretation
Relation of physical and social sciences:		
Subservient/inferiority relationship. Social science must strive to duplicate methods and results of physical science.	Integrative relationship. No necessary separation between physical and social sciences.	No clear relationship exists. Relational and interpretative nature of humanity makes clear relationship difficult.
Relation of humanity to nature:		
Expanding human dominance over nature	Holistic interpretation of human and natural symbiotic co-evolution	Unclear relational distinction between humans and nature
Methodological implications:		
Experimentation, quantification and search for fundamental laws	Integration of experiment-ation and interpretation. Fundamental laws and distinctive outcomes	Relational interpretations and undermining truth claims
Vision of Progress:		
There are no inherent limits to human knowledge	Significant limits to knowledge and progress	No fundamental order. Pure knowledge creation

and progress.	due to complexity and uncertainty.	and progress is impossible to know.
History is progressive, cumulative, and leads to an ultimate end.	History may progress and display fundamental patterns, but it is also uncertain and tortuous	History is relational hence it does not universally progress.

More importantly, for the social sciences if one accepts a complexity framework then one must abandon the rigid divisions and certainties of both modern and postmodern science and recognise the integrative nature of the physical and social sciences. Complexity theory argues that physical and social reality is composed of a wide range of interacting orderly, complex and disorderly phenomena. One can focus on different aspects, orderly (gravity or basic aspects of existence: life/death), complex (species evolution or institutional development) or disorderly (random chance or irrationality) but that does not mean that the others do not exist. Consequently, complexity theory demands a broad and open-minded approach to epistemological positions and methodological strategies without universalising particular positions or strategies. As Richardson and Cilliers argued:

> *If we allow different methods, we should allow them without granting a higher status to some of them. Thus, we need both mathematical equations and narrative descriptions. Perhaps one is more appropriate than the other under certain circumstances, but one should not be seen as more scientific than the other.*[xxxv]

These conclusions, "bridge the old divide between the two worlds (of natural and human sciences) without privileging the one above the other"[xxxvi].

A strategy for conceptualising the integrative nature of complexity is to look at how all types of complexity dynamics are reflected in the human condition. For example, using Figure 7 as a template we can produce an overview of the range of complexity dynamics of human phenomena. The key point to recognise is that there are both orderly and disorderly dynamics and that they are not hierarchically organised. A given human outcome, a decision to have coffee at breakfast or bomb a particular village, could be based on orderly, complex and disorderly dynamics with all being equally essential to the final outcome.

Figure 9: The Range of Complexity Dynamics in Human Phenomena

DISORDER ——————————————————— ORDER

Alinearity	**Conscious Complexity**	**Biotic Complexity**	**Abiotic Complexity**	**Linearity**
	Range of non-linear dynamic systems			

EXAMPLES

Random events, dreams, the unconscious.	Norms. Values. Language Narrative interpret-ation.	Group dynamics. Institutional processes.	Crowd dynamics. Electoral outcomes. Economic laws.	Basic physio-logical functions life/death

Beginning with linearity, the most fundamental and universalistic elements of human complexity are basic physiological functioning, in particular life and death. These physical boundaries and requirements, carbon based life forms requiring air, water and food to survive and reproduce, are the most orderly aspects of human existence. Deprived of these fundamentals, a human will die. What could be more orderly? As Peter Allen, a leading complexity thinker, argued, "orderly systems are dead systems".[xxxvii]

Moving into the range of complex systems, examples of mechanistic complexity in human systems would involve situations where individuals were forced to act in a mechanistic fashion. Traffic dynamics, choosing one road or another, crowd dynamics, choosing one exit or another and electoral outcomes, choosing one candidate or another are all examples of mechanical complex systems. Like mechanical complex system, relatively simple and stable patterns will emerge. However, this is no guarantee that these patterns will be continuously stable (traffic jams, crowd delays, landslide elections) nor is it possible to perfectly recreate the exact conditions of these events at a later time. The golden rules of abiotic complex systems apply.

Examples of organic complex systems in the human world can easily been seen in the organisational dynamics of economic and social institutions. As demonstrated by the huge growth in management and complexity literature, a business is a complex system that interacts with a larger complex environment (the market) that is very similar to the earlier model of a fish in a pond. General patterns emerge and the business is able to adapt to changes in its environment, but exact predictions and explanations of how a change in the environment will affect the business or the best strategies for the business to survive in the altered environment are impossible to know in advance.

An added layer of complexity in the human condition is its faculty of consciousness. Human beings create signs, symbols, myths, narratives and discourse in order to understand, control and exchange information about their surroundings. This ability adds another layer of complexity onto the human condition that is distinctive from the natural world. Examples of this conscious complexity include the creation of language, norms and values, and discourse. An example can be taken from virtually any type of human verbal interaction. A seemingly simple student-teacher relationship can be layered in historically, culturally and personally specific aspects that would be impossible to recreate in a different time and place.

Lastly, like the natural world, alinear human phenomena are nearly impossible to explain using examples since they are without a pattern and would have to be completely random. The closest common human experiences that readily come to mind would be the chaotic nature of dreams and the unconscious, random effects of certain disorders on the complex functioning of the brain and the phenomena of luck.

How can all of these dynamics be combined to explain a human phenomena? Let us begin with the phenomena of going to a shop to get a cup of coffee. I have a basic human need for water and nutrition that is very orderly and highly predictable. This is combined in the case of the coffee with the desire for a mildly addictive stimulant. As I leave my home to walk to the coffee shop, I immediately encounter crowd dynamics that may speed or impede my progress to the shops. When I reach my favourite coffee shop, I see that a new coffee shop is open on the opposite corner of the street competing for my business. These shops are engaged in the complex biotic process of competition. In a process of conscious complexity, I am enticed to enter the new shop by its pleasant name that reminds me of my childhood. As I enter the shop a woman is leaving with a cup of coffee. I open the door for her and say "good morning". As she turns to thank me a fly randomly lands on her face, blown there by a turbulent gust of wind from a passing bus. She has a dreadful fear of insects from the stories her grandmother used to tell her as a child and immediately flinches from the touch of the fly. The coffee spills, mostly on my pants. I return, change my pants and make a cup of coffee for myself at home. The point of detailing my pursuit of coffee is to demonstrate the remarkable linear, complex and alinear processes that are the foundation of most commonplace events in human existence.

But what if the stakes are higher, when lives are at stake, does complexity still apply? In 1971 Graham Allison, a leading Professor of Political Science at Harvard University, wrote *The Essence of Decision*, one of the greatest English language books in International Relations and the best book on the Cuban missile crisis. The basic story is well known. In 1962, responding to the deployment of US nuclear missiles in Turkey, the USSR began secretly deploying missile bases in Cuba. The bases were discovered and a blockade imposed on Cuba. The USSR challenged the blockade and threatened nuclear war, but eventually backed down dismantling the bases in Cuba. On the surface this would seem to be a simple game of threat and counter-threat that luckily for the lives of 100s of millions it did not go wrong. At one level this is correct. On the other hand, as Allison brilliantly demonstrated several different political and bureaucratic dynamics both between and within the USSR and USA were going on at the same time. Seemingly rational and irrational strategies emerge from the interplay of these dynamics. For example, when the Soviets were building the missile bases, they built them out in the open and in the same pattern as their bases in the USSR, making them easy to detect by US spyplanes, a clear strategic blunder. This was not caused by military stupidity or poor implementation, but caused by the centralised control over Soviet military engineers. The engineers were told to build missile bases in Cuba. They had a model from the USSR, in the open and in a certain pattern and they did as they were told. On the US side, the decision to form of naval blockade to stop the Soviets shipping the missiles to Cuba was fraught with military, bureaucratic and personal rivalries. In the end it may have come down to President Kennedy's personal naval experience that led him to choose a naval option. Overall, as Allison points out, these different dynamics could explain parts of the crisis, but none explained all of it. As President John F. Kennedy said after the crisis:

> *The essence of ultimate decision remains impenetrable to the observer – often, indeed, to the decider himself... There will always be the dark and tangled stretches in the decision-making process – mysterious even to those who may be most intimately involved.*[xxxviii]

Debates in Complexity Science

Not surprisingly, due to its growing popularity, evolution as a "New Age selling feature"[xxxix] and, most importantly, the breadth of its macro- and meta-theoretical implications, complexity theory is being applied in economics, policy, organisational studies, international relations and other areas and generates a significant variation in theoretical interpretations.[xl] Detailing these differences is clearly beyond the boundaries of this book. However, understanding the difference between modernist and postmodernist interpretations of complexity is important since it will have direct relevance to later applications.

For some, complexity is a strategy for going beyond a linear paradigm, but maintaining a modernist and progressive vision. In one of the major books on complexity and the social sciences, Daivd Byrne, claiming to follow in the footsteps of the scientific realism of the philosopher Roy Bhaskar[xli], argued that while "positivism was dead… and starting to smell"[xlii] and the relativism of postmodernism was "bone idleness promoted to a metatheoretical programme"[xliii]:

> Complexity/chaos offers the possibility of an engaged science not founded in pride, in the assertion of an absolute knowledge as the basis for social programmes, but rather in a humility about the complexity of the world coupled with a hopeful belief in the potential of human beings for doing something about it[xliv].

Moreover, for Byrne, 'complexity accounts are foundationalist [can provide a foundation for further knowledge], although they are absolutely not reductionist and positivist… (and) are surely part of the modernist programme'[xlv].

For others, in particular Paul Cilliers, complexity is best understood by postmodernists, particularly those working in the tradition of Derrida and Lyotard, because their theories 'have an implicit sensitivity for the complexity of the phenomena they deal with'[xlvi]. Cilliers certainly agrees with Byrne that complexity is non-reductionist and anti-positivist, but stresses that:

> Claiming that self-organisation is an important property of complex systems is to argue against foundationalism. The dynamic nature of self-organisation, where the structure of the system is continuously transformed through the interaction of contingent, external factors and historical, internal factors, cannot be explained by resorting to a single origin or to an immutable principle… self-organisation provides the mechanism whereby complex structure can evolve without having to postulate first beginnings… It is exactly in this sense that postmodern theory contributes to our understanding of complex self-organising systems[xlvii].

Generally, both authors have much in common. They both see the complexity framework as a challenge to linearity and reductionism. They both reject the relativism of some strands of postmodernism and argue that formal modelling is still possible, though significantly restrained under a complexity framework.

There differences are primarily those of degree and allegiances to certain theoretical traditions, but are important. For Byrne, coming from a more modernist orientation, complex systems theory represents a type of progress. In essence, more phenomena can be understood which enables individuals and state actors to exert more control over their lives and societies. For Cilliers, with a more postmodern orientation, complexity theory emphasises the uncertain and contingent and thus may expand our understanding, but cannot constitute a foundation for pure knowledge and hence be a gauge for progress. These differences are due to the level of complexity theory that one concentrates on. At its meso/macro theoretical level, complexity theory provides new tools for understanding these systems, hence it does seem progressive. At the same time, at the meta-theoretical level, it stresses that there are always orderly, complex and disorderly phenomena. Although one may be able to develop new ways and systems for understanding orderly and complex phenomena, there is always uncertainty and contingency in complex phenomena and the uncharted realm of disorder. Hence, it can appear as both foundationalist and anti-foundationalist.

Lastly, although neither Byrne nor Cilliers explicitly discuss it, complexity has obvious implications for both naturalists and anti-naturalists (those who support and oppose the use of physical science theories and methods in the social sciences). Again, drawing on critical realism and the 'non-positivist' or 'critical' naturalism Bhaskar, both try to use complexity as a bridge to link the natural and social sciences. Both want to break down the barriers between the major fields of knowledge, mirroring the conclusions of the Gulbenkian Commission, but neither wants to impose a new unifying 'scientific' law on the social realm. In essence, they want to open up the sciences, 'not only towards the world, but also internally. The barriers between the various scientific disciplines need to be crossed'[xlviii]. In this sense, complexity theory is a direct challenge to strong naturalists and anti-naturalists who argue for the complete dominance or distinctiveness of one type of science over or from another, or who reject the possibility of some types of generalisable scientific knowledge.

A Question of Method

As mentioned above, complexity implies methodological pluralism. However, this does not mean that all methodological strategies are appropriate for all phenomena. Linear, reductionist, quantitative and predictive methods can be more applicable to certain social phenomena and less so to others. This goes for non-linear methods as well. An excellent way for visually conceptualising this constrained methodological pluralism was created by David Harvey and Michael Reed. Building on the work of Kenneth Boulding and Neil Smelser[xlix] they created a hierarchy of ontological complexity in social systems. By combining this on a matrix with a liner layout of levels of modelling abstraction, more linear (left) to less linear (right) they produced the following Figure.

Levels of Complexity in Social Phenomena	Levels of Modelling Abstraction (From left to right, moving from more prediction to greater description)				
Alinear			X	X	X
Conscious complexity		X	X	X	X
Biotic Complexity	X	X	X	X	X
Abiotic Complexity	X	X	X	X	
Linear	X	X	X		
	Predictive Modelling	Statistical Modelling	Ideal Type Modelling	Historical Narratives	Deconstructive Techniques

Figure 10. Demonstrates the general range of fit between the level of complexity in social phenomena and the general range of methodological strategies.[l]

One could certainly quibble over the exact divisions of ontological complexity or whether more methods could be added to the left or right of the levels of modelling. Nevertheless, the underlying principle that only extremely orderly or disorderly phenomena can be explored with one or a few methodological strategies while the vast range of complex social phenomena must be explore with the full panoply of methodological strategies undermines hierarchical assumptions about methodologies and rejects a radical relativist positions as well.

In this book we will be focusing on complex political, economic and social phenomena that require a wide variety of methodological strategies. Emerging as it did out of the physical sciences and finding an early home at the computer oriented Santa Fe Institute, it is no surprise that many of complexity’s most exciting discoveries and biggest claims come from its potential in the field of computer modelling. Detailed discussions and descriptions of these modelling techniques are readily available and are increasingly being explored by a growing range of social scientists[li]. We will not explore complexity modelling in detail for three main reasons. It is beyond the range of this book and others cover it well. Also, we feel that although modelling can provide intriguing insights to some phenomena and add an entertaining presentational effect for students and neophytes, it is only one methodological tool among many and hence is not be privileged in such a general work.

Complexity and the Politics of Order

Why is the complexity framework so radical and important? The Newtonian paradigm had much to commend it. It helped to lift the miasma of religious interpretation from the eyes of Renaissance thinkers. It fired the desire of countless academic, scientists and philosophers to “to strive, to seek, to find and not to yield”[lii] and was the foundation of the industrial revolution. Its fundamental weakness was its arrogance. For a Newtonian thinker, with the complete knowledge of nature and humanity, they could be gods and create heaven on Earth. By the 20th century, flushed with the heady success of mechanistic and industrial achievement and the growing power and capabilities of the state, no problem seemed beyond the grasp of humanity. Social scientists merely wedded this orderly vision and arrogance to the social realm and produced the fundamental visions of social order, communism and capitalism, which structured the history of the 20th century. Many had the best of intentions, hoping to make the world of better place for all time, the final order. That these visions led to the extreme forms of human suffering and environmental degradation in large parts of the globe was certainly a setback for their dreams and the Newtonian framework.

Does this mean the end of progress? Are we back to Nietzscheian nihilism or Heideggerian fatalism in the face of forces beyond our control? This book is clearly focused on attacking the cult of order. We have chosen this focus due to its dominance in the 20th century. However, complexity is an equal challenge to the cult of disorder. That human beings cannot be gods, that we live in a symbiotic relationship with each other and nature and that we do not have complete control over our lives and hence complete freedom does not imply failure and apathy. As a leading complexity thinker, Klaus Mainzer, put it:

> *The complex system approach cannot explain to us* ***wha****t life is. But it can show us* ***how*** *complex and sensitive life is. Thus it can help us to become aware of the value of our life*[liii]

Reverting to apathy will not solve our problems and may easily lead our complex human system into a more negative “attractor state”. The need to respond to the threat of global warming immediately springs to mind. In essence, apathy is just as blind as a desperate attempt to find the new, new order or to buttress and defend an existing one. The problem with both the orderist and disorderist positions is that they refuse to recognise the complex and uncertain reality that surrounds them. That it is uncertain does not mean it cannot progress, but it will not progress in a clear path. In some ways a disorderist position is as arrogant as an orderist position, both know the future. One is desperate to make the present squeeze into a given future. The other is unwilling to do anything about the present because it is already heading to a given future.

Once one abandons the arrogance of order and disorder and accepts the humbling limits of knowledge and uncertain potential which complexity implies then a new politics emerges: a politics of uncertainty, but also of openness, of mistakes and learning, of failure and adaptation. Exploring this new politics is what this book is all about.

However, before we can begin this exploration, we need to examine the new tools that complexity provides. For not only does complexity provide a new paradigmatic world view of science and society, it also provides a new range of tools for understanding and interpreting the complex reality of the 21st century.

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[i] *New Atlantis* (1627), in *Oxford Dictionary of Citations* (25:26).

[ii] In J. B. Birks, *Rutherford at Manchester* (1962) p.108.

[iii] *Epitaph intended for Sir Isaac Newton Oxford Dictionary of Quotations* (251:26).

[iv] Introduction to Quantum theory, 2000 p.159.

[v] Horgan, *The End of Science* 1996, p.19. It is rumoured that he later regretted the now famous quote.

[vi] Horgan. *The End of Science*, 1996, p. 31.

[vii] Wilson, *Consilience*, 1998, p.291.

[viii] Coveney and Highfield *Frontiers of Complexity* 1996, p.169

[ix] For a philosophical discussion of the process of transformation, including the switch from linear to nonlinear thinking, see Ferguson (1983). Hawking 1988: 1-14), on the other hand, provides an insightful technical analysis of the way scientific beliefs and methods changed through the ages. The Uncertainty Principle advanced by Heisenberg had a particularly pivotal impact on the future course of scientific research. For a review of developments in physics see Davies (1987) and Peat (1991).

[x] A similar review of complexity can be found in Geyer 2002. Major works on complexity include: Bar-Yam (1997), Capra (1991), Coveney and Highfield (1995), Gell-Mann (1994), Gleick (1988), Kauffman (1993 and 1995) and Waldrop (1992).

[xi] See Gleick, 1987.

[xii] Gleick, 1987 p.25.

[xiii] This figure is taken from Gleick, *Chaos*, 1987, p.27.

[xiv] Allen, 'What is Complexity Science' *Emergence*, vol3, #1, 2001.

[xv]The literature on the complexity paradigm and abiotic complex systems has now become quite large. Key works include: Nicolis (1989), Coveney (1996) and Kauffman (1993, 1996). In addition, Waldrop (1994) and Lwein (1997) present an excellent general introduction to Complexity.

[xvi] We need references to these guys and gals…

[xvii] Lewin 1999: 15

[xviii] Coveny and Highfield 1995: 330

[xix] Kauffmann 1993

[xx] Capra 1996; Fleischaker 1992; Lovelock 1972 and 1979 and Margulis 1993.

[xxi] Coveney and Highfield: 234-5

[xxii] Wilson, *Consilience*, p.21.

[xxiii] Klaus Mainzer, *Thinking in Complexity* p.264.

[xxiv] Gulbenkian Commission 1996: 7.

[xxv] Strong 1962: v.

[xxvi] Fukuyama's "End of History" thesis continues to resonate with elite and mass opinion particularly after the events of September 11. See Fukuyama's article "How the West Has Won*" The Guardian* 11 October 2001.

[xxvii] For a discussion of the simple-complex dichotomy in ancient Greek philosophy see: Heinz Herrmann, From Biology to Sociopolitics: Conceptual Continuity in Complex Systems, New Haven: Yale University Press, 1998.

[xxviii] Mainzer, *Thinking in Complexity* p,.83. This led Kant to conclude that "The Newton (for) explaining a blade of grass cannot be found".

[xxix] Mainzer, *Thinking in complexity*, p.84.

[xxx] F. A. Hayek, Studies in Philosophy, Politics and Economics. Chicago: University of Chicago Press, 1967, p.42.

[xxxi] For a review of the role of laws in the social sciences see: Martin and McIntyre (1996).

[xxxii] Eagleton 1996: vii

[xxxiii] Hay 2002: 227

[xxxiv] For discussions of the development of the debate between these two sides see: Bevir (1999), Bhaskar (1986), Byrne (1998) and Cilliers (1998), Delanty (1997) and Rasch and Wolfe (2000).

[xxxv] Richardson and Cilliers 2001: 12.

[xxxvi] Richardsen and Cillers, 2001: 11.

[xxxvii] See: www.liv.ac.uk/complexitynetwork conference presentation April 2002.

[xxxviii] Quoted in Graham Allison, *Essence of Decision: Explaining the Cuban Missile Crisis* (Boston: Little, Brown and Company) 1971: VI.

[xxxix] Thrift 1999

[xl] Non-linear systems theory (complexity theory) has established footholds in all of the major areas of social science. In philosophy and social theory see: Byrne (1998) and Cilliers (1998). In economics see: Barnett *et al.* (1989), Day and Samuelson (1994), Hodgson (1997), Mirowski (1994), Ormerod (1994 and 1998). In organisational and management theory see Stacey (1999) and Stacey *et al*. (2000). In sociology and politics see: Cioffi-Revilla (1998), Eve *et al*. (1997), Kiel and Elliott (1997), Rycroft and Kash (1999). In development theory see: Rihani and Geyer (2001) and Rihani (2002). In political theory see: Geyer (2002) and Scott (1998). In international relations see: Jervis, R. (1998). For an excellent overview of the spread of complexity theory and a critical review of its popularisers see: Thrift (1999).

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

[xlii] Byrne 1998, 37

[xliii] Byrne 1998, 45

[xliv] Byrne 1998, 45

[xlv] Byrne 1998, 35

[xlvi] Cilliers 1998, iix

[xlvii] Cilliers 1998, 106

[xlviii] Cilliers 1998, 127

[xlix] Kenneth Boulding (1968) and Neil Smelser (1963)

[l] Keil and Elliot p.307

[li] Axelrod 1997, Axelrod and Cohen 2000, Kiel and Elliot 1997. Celso Grebogi and James A. Yorke (eds.) *The Impact of Chaos on Science and Society*, Tokyo: United Nations University Press, 1997. Saul Krasner, (ed.) The Ubiquity of Chaos, Washington DC: The American Association for the Advancement of Science, 1990.

[lii] Tennyson, *Ulysses*, 1842. L.67

[liii] Mainzer, Thinking in Complexity, p.325